REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 074-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE Sept 96	3. REPORT TYPE AND DATES COVERED Technical Report

4. TITLE AND SUBTITLE

Characterization of Emissions Produced by the Open Burning/Open Detonation of Complex Munitions

5. FUNDING NUMBERS

Contract No. DAAD09-92-D-0004

6. AUTHOR(S)

J.L Wilcox, B. Entezam, M.J. Molenaar, & T.R. Shreeve

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Physical Test Division
West Desert Test Center

Andrulis Research Corporation

8. PERFORMING ORGANIZATION REPORT NUMBER

N/A

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

SERDP
901 North Stuart St. Suite 303
Arlington, VA 22203

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

DPG Document No. DPG-TR-96-016

11. SUPPLEMENTARY NOTES

Technical report written for the U.S. Army Dugway Proving Ground, Dugway, UT 84022-5000. This work was supported in part by SERDP under Contract No. DAAD09-92-D-0004. The United States Government has a royalty-free license throughout the world in all copyrightable material contained herein.

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13. ABSTRACT ***(Maximum 200 Words)***

This report presents the results of a series of test trials sponsored by SERDP to identify and quantify the emissions produced by the open burning (OB) and open detonation (OD) treatment of selected propellant, explosive, and pyrotechnic (PEP) energetic materials (EMs), The SERDP is an interagency effort which sponsored defense-related environmental research objectives to meet the needs of the DoD, the DOE, and the EPA, and Pyrotechnic Thermal Treatment Evaluation Test Facility, commonly referred to as the BangBox, located at West Desert Test Center (WDTC), U.S. Army Dugway Proving Ground (DPG), Utah.

14. SUBJECT TERMS	15. NUMBER OF PAGES
SERDP, PEP material, Open burning (OB), Open detonation	94
	16. PRICE CODE N/A

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
unclass.	unclass.	unclass.	UL

SERDP

DPG Document No. DPG-TR-96-015

CHARACTERIZATION OF EMISSIONS PRODUCED BY THE OPEN BURNING/OPEN DETONATION OF COMPLEX MUNITIONS

By

James L. Wilcox

Physical Test Division
West Desert Test Center

Ben Entezam
Michael J. Molenaar
Thomas Russell Shreeve

Andrulis Research Corporation
Contract No. DAAD09-92-D-0004

SEPTEMBER 1996

U. S. ARMY DUGWAY PROVING GROUND
DUGWAY, UTAH 84022-5000

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ACKNOWLEDGMENTS

The authors would like to thank Dr. William Mitchell, United States Environmental Protection Agency (EPA), Research Triangle Park, North Carolina; Radian Corporation, Research Triangle Park, North Carolina; Oregon Graduate Institute of Science and Technology (OGI), Beaverton, Oregon; Mountain States Analytical, Incorporated (MSAI), Salt Lake City, Utah; and Lockheed Corporation, DPG; for their contribution to the success of this study.

In addition, special thanks are given to the following Andrulis Research Corporation employees for their help in manuscript preparation and technical editing: Mr. Lacy Hancock, Ms. Cheri Martens, Ms. Carol Hanzelka, Ms. Linda Jorgensen, and Ms. Juliette Mestas.

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EXECUTIVE SUMMARY

This report presents the results of a series of test trials sponsored by the Strategic Environmental Research and Development Program (SERDP) to identify and quantify the emissions produced by the open burning (OB) and open detonation (OD) treatment of selected propellant, explosive, and pyrotechnic (PEP) energetic materials (EMs). The SERDP is an interagency effort which sponsors defense-related environmental research objectives to meet the needs of the U.S. Department of Defense (DOD), the U.S. Department of Energy (DOE), and the U.S. Environmental Protection Agency (EPA). The test trials were conducted in the Propellant, Explosive, and Pyrotechnic Thermal Treatment Evaluation Test Facility, commonly referred to as the BangBox, located at West Desert Test Center (WDTC), U.S. Army Dugway Proving Ground (DPG), Utah.

The BangBox is an approximately 950-m^3 flexible hemisphere that uses the U.S. Army Armament, Munitions, and Chemical Command (AMCCOM) OB/OD thermal treatment emissions system successfully audited by several environmental agencies. This system consists of the BangBox facility and a network of laboratories specializing in the sampling and assaying of inorganic gases, volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), and metals found in the atmosphere at trace levels.

The test had four objectives: (1) determine the suitability of the existing BangBox testing procedures for items of distinctly different physical or chemical characteristics from items previously tested; (2) characterize the emissions generated from the OD treatment of selected surrogate items representative of PEP materials currently in the demilitarization inventory; (3) characterize the emissions resulting from OB treatment of energetic-contaminated waste materials; and (4) characterize the emissions generated from the OD treatment of material surrounded by water-filled polyethylene bags used to attenuate noise generated from OD treatment of energetic material.

The emissions were characterized by determining emission factors (the ratio of the mass of chemical species generated to the mass of EM of the PEP item burned or detonated) for a variety of target analytes. The target analytes included 6 inorganic gases, more than 100 VOCs and SVOCs, and 15 metals. Emission factors are used to predict the quantities of target pollutants generated from larger-scale, open-air OB/OD treatment of the materials tested in support of Resource Conservation and Recovery Act (RCRA), Subpart X permit applications for OB/OD treatment of items contained within the DOD demilitarization munitions inventory.

Emission factors were calculated from the detonation of detonating cord, tritonal surrogate, tritonal surrogate with calcium stearate, tritonal surrogate surrounded by water, amatol surrogate, amatol surrogate surrounded by water, composition B surrogate, composition B surrogate with aluminum (HBX), and the burning of propellant manufacturer's waste and diesel fuel and dunnage.

Data analyses also included calculation of emission factors for dioxins and furans from the burning of propellant manufacturer's waste and diesel fuel and dunnage, characterization of the residues from the detonation of tritonal surrogate surrounded by water, and amatol surrogate surrounded by water and the burning of propellant manufacturer's waste and diesel fuel and dunnage, and determination of the percent chlorine recovered as HCl and Cl_2 from the burning of propellant manufacturer's waste.

Sampling instruments within the BangBox included high-volume continuous-flow samplers, SUMMA® sampling canisters, and real-time gas analyzers. Laboratory assay was conducted using gas chromatography (GC)/flame ionization detection (FID), GC/mass

spectrometry (MS), cold vapor atomic absorption (CVAA), and inductively coupled plasma (ICP)/optical emission spectrometry (OES).

The emission factors obtained from these trials are now being combined with those from the other PEP materials previously studied in the BangBox. The resulting database will then be statistically examined to determine if PEP materials can be classified into "emission product families" based on the chemical composition of the PEP material. The statistical analysis will also determine: (1) if the number of background samples and/or field samples collected for each PEP material can be reduced or should be increased; (2) if the target analyte list, sampling methods, or the sample-collecting times should be changed; and (3) if there are artifact pollutants which should be removed from the test data. A database management system, which will provide access to the BangBox data via the DOD Munitions Items Disposition Action System (MIDAS), is also being developed.

Quality assurance support for the test was provided by the EPA. Representatives from its Atmospheric Research and Exposure Assessment Laboratory's Quality Assurance Division visited the test site and supporting laboratories.

SECTION 1. INTRODUCTION

1.1 BACKGROUND

1.1.1 Limited Options for Disposing of Energetic Materials (EMs)

To maintain a constant state of readiness, U.S. Department of Defense (DOD) installations manufacture and store a diverse inventory of propellant, explosive, and pyrotechnic (PEP) EMs. Those items that can no longer fulfill their original function, or are otherwise unwanted, must be safely destroyed. Treatment methods such as incineration and deactivation, recovery, and recycling are inappropriate for many PEP materials because their composition is either unknown, unstable, or degraded. Furthermore, most PEP materials cannot be disassembled safely, and the development of a deactivation, recovery, and recycling program cannot be financially justified. As a result, the only available treatment method for many PEP materials is open-air thermal destruction. Frequently referred to as open burning (OB) and open detonation (OD), this method has been proven safe, efficient, and effective (Reference 1).

1.1.2 The Requirement for Open Burning/Open Detonation (OB/OD) Emissions Data

Developing information to characterize the emissions produced by OB/OD treatment of EMs is necessary for the acquisition of permits from the reigning state and/or the U.S. Environmental Protection Agency (EPA) regional agency as specified by the Resource Conservation and Recovery Act (RCRA) in 40 Code of Federal Regulations (CFR) Part 264, Subpart X (Reference 2) and the Clean Air Act Amendments (Reference 3). The requirements of a RCRA Subpart X permit (Reference 2) include identification and quantification of the chemicals produced by the treatment method.

1.1.3 The BangBox Open Burning/Open Detonation (OB/OD) Test Program

The Department of the Army established a testing program at the U.S. Army Dugway Proving Ground's (DPG's) West Desert Test Center (WDTC) in Utah to demonstrate compliance of OB/OD operations with Federal and state environmental regulations. Tests were conducted in the Propellent, Explosive, and Pyrotechnic Thermal Treatment Evaluation and Test Facility, commonly referred to as the BangBox (Reference 4). The BangBox is a hemispherically-shaped structure that allows the emissions produced from the burning or detonation of test items to be sampled. The sampled emissions are assayed to determine the quantity of target analytes generated and this information is used to calculate emission factors (the ratio of the mass of target analyte generated to the mass of PEP material burned or detonated) for the item tested.

After DPG personnel concluded the field-testing phase of the BangBox study (Reference 5), EPA Region VIII personnel reviewed both methodology and data. They ultimately confirmed that the data collected from the BangBox testing facility closely represented actual field emissions and could support the emissions characterization necessary for the risk assessment requirements of RCRA Subpart X permits (Reference 2). The EPA Region VIII Subpart X Coordinator wrote:

> This BangBox project represents a major step toward characterizing the emissions resulting from the open burning and/or open detonation of explosive wastes. Pursuant to 40 CFR 264.600, it is EPA Region VIII's policy to require all Resource Conservation and Recovery Act (RCRA) Part B permit applications submitted for units that OB/OD explosive hazardous waste to provide such emissions characterization...The BangBox procedure has the potential to provide the needed degree of characterization for many of the explosive wastes that are generated by the Department of Defense (DOD)... data generated [from] the BangBox tests... [are presently]

viewed by EPA Region VIII as the best currently available data for each munitions that is tested.

1.1.4 Need for Additional Testing

The DOD's demilitarization inventory currently contains large quantities of waste munitions and explosive materials that can be treated by OB/OD disposal methods. However, logistics and the lack of larger-capacity test chambers delayed the study of OB/OD treatment for many of these PEP materials. Additionally, past testing did not address OB/OD treatment of the waste materials generated from the manufacture of conventional EMs, nor did it address the impact of OB/OD treatment noise reduction methods on the emissions produced. These issues are among the specific objectives of this test listed in Paragraph 1.2.

1.1.5 The Issue of Noise Attenuation from Open Detonation (OD) Operations

Noise generation from OD treatment of EMs has become an issue of increasing concern. As population centers expand toward once-isolated depots, arsenals, and other military sites, citizens are voicing complaints about the noise generated by OD treatment. In response, local regulators have requested that OD treatment facility managers develop procedures to attenuate the noise or that OD treatment sites be moved to more remote locations. Many managers consider the latter option to be cost prohibitive and are concerned about the potential dangers associated with moving old, deteriorating energetic material. These issues have also arisen in Europe where it is more difficult to separate military activities from populated areas. The United Kingdom (UK) has developed a sound-attenuation system using large plastic bags filled with water placed over material to be treated by OD. Although this method has been successful, the UK has not released any data regarding the characterization of the emissions generated by the procedure. Because of this, one of the objectives of this test is to characterize the emissions generated from the OB/OD treatment of energetic material surrounded by water-filled bags.

1.2 TEST OBJECTIVES

The specific objectives of the test are summarized as follows:

a. Determine the suitability of current BangBox testing procedures for items of distinctly different physical or chemical characteristics from items previously tested.

b. Characterize the emissions generated from the OB/OD treatment of selected surrogate items representative of PEP materials currently in the demilitarization inventory.

c. Characterize the emissions generated from the OB/OD treatment of energetic material surrounded by water in plastic bags.

d. Characterize the emissions resulting from OB/OD treatment of EMs and energetic-contaminated waste materials.

SECTION 2. TEST ITEMS

2.1 DESCRIPTION

The following items are listed in the order in which they were tested. The munitions were chosen because they represent munitions currently in the DOD demilitarization inventory.

2.1.1 Detonating Cord
NSN 1375-00-204-0851

2.1.1.1 Purpose. The purpose of the detonating cord detonation trials was to verify that the BangBox and its systems were ready for testing and to sample and analyze the emission products from the OD treatment of detonating cord. Detonating cord is widely used throughout the DoD for purposes such as linking and/or initiating other explosive charges. Table 2.1 describes the nominal composition of the detonating cord used in the trials.

2.1.1.2 Preparation for Testing. A 21.3-m length of detonating cord was wrapped around a 61-cm diameter metal drum and exposed to sunlight for approximately 2 hours to allow it to soften. The detonating cord was then reformed into a loose coil of approximately 61 cm in diameter. Successive turns of the coil were tied together with cotton string, at approximately four locations per turn, so they would be separated by a minimum of 2.5 cm when the entire coil was suspended.

2.1.1.3 Test Setup. The entire coil was hung from cotton string tied between two support rods and attached to an M6 blasting cap at its upper end. The resulting mass of energetic material (MEM) of this charge was 203.01 g.

2.1.2 Tritonal Surrogate

2.1.2.1 Purpose. The purpose of the tritonal surrogate trials was to sample and analyze the emission products from the OD treatment of low-density tritonal (80 percent TNT/20 percent aluminum). Tritonal is a secondary explosive used in the manufacture of bombs. A surrogate was prepared on-site under the supervision of the program's energetic-materials expert consultant. The nominal composition of the tritonal surrogate used in the test is described in Table 2.2.

2.1.2.2 Preparation for Testing. Blocks of trinitrotoluene (TNT) were broken into a medium-fine powder on a plastic sheet using a rolling pin and stored in a polyethylene freezer bag until 1274 g of powdered TNT was collected. The powdered TNT was then mixed with 431 g of fine aluminum powder through layering and rolling of the components in a 3.79-L bottle until the mix appeared uniform.

2.1.2.3 Test Setup. Three 227-g portions of the mix (consisting of 181.6 g crushed TNT and 45.4 g aluminum powder) were placed in individual thin polyethylene bags. One bag per trial was suspended with cotton string tied to another cotton string stretched between two support rods. In all trials, the charges were suspended a minimum of 100 cm above the floor. Because single M6 blasting caps did not perform well as an initiator by themselves in Trials 1 and 2, the M6 blasting cap was inserted into a 6.5-g composition C-4 donor charge for Trial 3.

2.1.3 Tritonal Surrogate with Calcium Stearate

2.1.3.1 Purpose. The purpose of the tritonal surrogate with calcium stearate trials was to sample and analyze the emission products from the detonation of low-density tritonal (80 percent TNT/ 20 percent aluminum) with an organic additive used to simulate non-explosive organic materials

Table 2.1. Nominal Composition of Detonating Cord Used in the Detonating Cord Detonation Trials.

Ingredient	Mass (%)
Pentaerythritol tetranitrate (PETN)	100.0
Nylon	NA[a]

[a]Not applicable (item was used to support the test setup).

Table 2.2. Nominal Composition of Material Used in the Tritonal Surrogate Detonation Trials.

Ingredient	Mass (%)
Trinitrotoluene (TNT)	79.25
Aluminum	20.75
C-4 donor charge	NA[a]
Polyethylene bag	NA

[a]Not applicable (items were used to support the test setup).

in bombs. Tritonal is a secondary explosive used in the manufacture of bombs. Calcium stearate provided a good substitute for many of the minor organic materials such as asphalts and ester gums introduced during the manufacturing process. The nominal composition of the tritonal surrogate with calcium stearate used in the test is described in Table 2.3.

2.1.3.2 Preparation for Testing. For each trial, 216 g of the mix remaining from the tritonal surrogate trials were mixed with 11 g of calcium stearate to produce a 227-g mix.

2.1.3.3 Test Setup. Each 227-g mix was placed in a thin polyethylene bag. One bag per trial was suspended with cotton string tied to another cotton string stretched between two support rods. In all trials, the charge was suspended a minimum of 100 cm above the floor. The initiator consisted of one M6 blasting cap inserted into a 6.5-g composition C-4 donor charge.

2.1.4 Amatol Surrogate

2.1.4.1 Purpose. The purpose of the amatol surrogate trials was to sample and analyze the emission products from the detonation of low-density amatol (50 percent TNT/50 percent ammonium nitrate). Amatol is a secondary explosive used in munitions of various size and application. A surrogate for amatol was prepared on-site under the supervision of the program's EMs expert consultant. Table 2.4 describes the nominal composition of amatol surrogate used in the test.

2.1.4.2 Preparation for Testing. A TNT block was broken into a medium-fine powder on a plastic sheet with a rolling pin. Three 227-g mixes were prepared, each by mixing 113.5 g of the powdered TNT with 113.5 g of ammonium nitrate.

Table 2.3. Nominal Composition of Material Used in the Tritonal Surrogate with Calcium Stearate Detonation Trials.

Ingredient	Mass (%)
Trinitrotoluene (TNT)	78.0
Aluminum	19.5
Calcium stearate	2.5
C-4 donor charge	NA[a]
Polyethylene bag	NA

[a]Not applicable (items were used to support the test setup).

Table 2.4. Nominal Composition of Material Used in the Amatol Surrogate Detonation Trials.

Ingredient	Mass (%)
Trinitrotoluene (TNT)	50
Ammonium nitrate	50
C-4 donor charge	NA[a]
Polyethylene bag	NA

[a]Not applicable (items were used to support the test setup).

2.1.4.3 Test Setup. Each 227-g mix was placed in a thin polyethylene bag. One bag per trial was suspended with cotton string tied to another cotton string stretched between two support rods. Each bag was suspended a minimum of 100 cm above the floor. The initiator consisted of 6.5 g of composition C-4 molded around one M6 blasting cap.

2.1.5 Composition B Surrogate

2.1.5.1 Purpose. The purpose of these trials was to sample and analyze the emissions produced from the detonation of low-density composition B charge [58 percent hexamethylenetrinitroamine (RDX)/38 percent TNT/4 percent wax]. Composition B is a secondary explosive found in a wide variety of munitions including aerial bombs and artillery projectiles. A surrogate for composition B was prepared on-site under the supervision of the program's EMs expert consultant. Table 2.5 describes the nominal composition of the composition B surrogate used in the test.

2.1.5.2 Preparation for Testing. Crushed TNT was mixed with composition C-4 through tumbling and rolling to produce three 227-g charges.

2.1.5.3 Test Setup. Individual 227-g charges were placed in thin polyethylene bags. One bag per trial was suspended with cotton string tied to another cotton string stretched between two support rods. For each trial, the bags were suspended a minimum of 100 cm above the floor. The initiator consisted of 6.5 g of composition C-4 molded around one M6 blasting cap.

Table 2.5. Nominal Composition of Material Used in the Composition B Surrogate Detonation Trials.

Ingredient	Mass (%)
Hexamethylenetrinitroamine (RDX)	56.42
Trinitrotoluene (TNT)	38.00
Wax	5.58
C-4 donor charge	NA[a]
Polyethylene bag	NA

[a]Not applicable (items were used to support the test setup).

2.1.6 Composition B Surrogate with Aluminum (HBX)

2.1.6.1 Purpose. The purpose of these trials was to sample and analyze the emission products from the detonation of low-density HBX charges of 48.1 percent RDX, 31.5 percent TNT, 17 percent aluminum, and 3.4 percent wax. HBX is a secondary explosive used in large ordnance such as bombs, depth charges, and torpedoes. Table 2.6 describes the nominal composition of the HBX used in the test.

2.1.6.2 Preparation for Testing. Crushed TNT was mixed with composition C-4 through tumbling and rolling to produce three 227-g charges.

2.1.6.3 Test Setup. Each 227-g charge was placed in a thin polyethylene bag. One bag per trial was suspended with cotton string tied to another cotton string stretched between two support rods. For each trial, the bags were suspended a minimum of 100 cm above the floor. The initiator consisted of 6.5 g of composition C-4 molded around one M6 blasting cap.

2.1.7 Tritonal Surrogate Surrounded by Water

2.1.7.1 Purpose. The purpose of these trials was to sample and analyze the emission products from the detonation of low-density tritonal (80 percent TNT/20 percent aluminum) surrounded by bags of water. A surrogate for tritonal was prepared on-site under the supervision of the program's EMs expert consultant. Table 2.7 describes the nominal composition of the tritonal surrogate surrounded by water used in the test.

2.1.7.2 Preparation for Testing. Unused tritonal mix from the tritonal surrogate trials was used. The water was contained in 0.946-L polyethylene bags.

2.1.7.3 Test Setup. Each charge was placed in two polyethylene bags to protect against water leakage. The protected charge was supported between three 0.946-L polyethylene bags, each containing 454 g of water. For Trial 3, the same amount of water (1362 g) was divided among five 0.946-L polyethylene bags. One of the additional bags was placed on the top of the charge and the other on the bottom. A single M6 blasting cap and 6.5 g of composition C-4 donor charge initiated the material.

2.1.8 Manufacturer's Waste

2.1.8.1 Purpose. The purpose of these trials was to sample and analyze the emission products from the burning of waste generated from the manufacture of EMs. The composition of the

Table 2.6. Nominal Composition of Material Used in the Aluminized Composition B (HBX) Detonation Trials.

Ingredient	Mass (%)
Hexamethylenetrinitroamine (RDX)	48.02
Trinitrotoluene (TNT)	31.58
Wax	3.43
Powdered aluminum	16.97
C-4 donor charge	NA[a]
Polyethylene bag	NA

[a]Not applicable (items were used to support the test setup).

Table 2.7. Nominal Composition of Material Used in the Tritonal Surrogate Surrounded by Water Detonation Trials.

Ingredient	Mass (%)
Trinitrotoluene (TNT)	79.25
Aluminum	20.75
C-4 donor charge	NA[a]
Water	NA
Polyethylene bag	NA

[a]Not applicable (items were used to support the test setup).

waste was designed to be representative of the industry. Table 2.8 describes the nominal composition of the waste material tested.

2.1.8.2 Preparation for Testing. The manufacturer's waste was delivered premixed to the test site in individual polyethylene bags. No special preparations were required.

2.1.8.3 Test Setup. The Trial 1 charge was placed in a stainless steel burn pan prior to burning. The Trial 2 and 3 charges were placed on a 7.6-cm layer of pea gravel poured into the pan because the Trial 1 charge burned a hole through the bottom of the pan. This method prevented holes from burning through the bottom of the pan, but allowed a hole to burn through the side and also resulted in melted plastics becoming embedded in the gravel. Each test was initiated with 4 g of Hercules Unique™ smokeless powder in a cloth powder bag placed in crumpled paper and ignited with an M1A1 electric squib.

2.1.9 Amatol Surrogate Surrounded by Water

2.1.10 Purpose. The purpose of these trials was to sample and analyze the emission products form the detonation of low-density amatol (50 percent TNT/50 percent ammonium nitrate) surrounded by bags of water. Amatol is a secondary explosive used in munitions of various size and application. A surrogate for amatol was prepared on-site under the supervision of the program's EMs expert consultant. Table 2.9 describes the nominal composition of the amatol surrogate surrounded by water used in the test.

Table 2.8. Nominal Composition of Material Used in the Manufacturer's Waste Burning Trials.

Ingredient	Mass (%)
Aluminized propellant[a]	65.00
Plastic materials[b]	20.00
Paper, cloth, and wood[c]	11.00
Diesel fuel	4.00
Ignition supplement[d]	NA[e]
Polyethylene bag	NA

[a]Sixty nine percent ammonium perchlorate, 19 percent aluminum, 12 percent other.
[b]Includes gloves and antistatic polyethylene plastic.
[c]Shredded Kimwipes® wipers, rymple cloth, and wooden tongue depressors.
[d]Hercules Unique™ smokeless powder.
[e]Not applicable (items were used to support the test setup).

2.1.10.1 Preparation for Testing. Mix remaining from the amatol surrogate trials was used for each trial. The water was contained separately in 0.946-L polyethylene bags.

2.1.10.2 Test Setup. Each charge was placed in an additional 0.946-L polyethylene bag as protection against water leakage. Three pounds of water were distributed equally among five 0.946-L polyethylene bags. One bag was placed under the charge, three were placed along the sides of the charge, and one was placed on top of the charge. The entire assembly was enclosed within a 3.786-L polyethylene bag.

2.1.11 Diesel Fuel and Dunnage

2.1.11.1 Purpose. The purpose of these trials was to sample and analyze the emission products from a simulated bonfire used in the field to destroy a variety of small munitions. Wood from ammunition boxes, paper, Styrofoam™ packing, and diesel fuel were used during these trials. Table 2.10 presents the nominal composition of the diesel fuel and dunnage material tested.

2.1.11.2 Preparation for Testing. Styrofoam™, pasteboard, and wood were broken and cut into irregularly-sized small pieces, convenient for burning.

2.1.11.3 Test Setup. The items were placed in a stainless steel burn pan. The wood was split into small kindling and placed over the other materials. Diesel fuel was poured over much of the paper and exposed to the igniter. Each trial was initiated with 4 g of Hercules Unique™ smokeless powder in a cloth bag placed in crumpled paper and ignited with an M1A1 electric squib.

2.2 MASS OF ENERGETIC MATERIAL (MEM)

The MEM of the PEP test items used to calculate the emission factors are summarized in Table 2.11.

2.3 TEST MATRIX

Testing was conducted from 15 to 30 August 1995. The test matrix is presented in Table 2.12.

Table 2.9. Nominal Composition of Material Used in the Amatol Surrogate Surrounded by Water Detonation Trials.

Ingredient	Mass (%)
Trinitrotoluene (TNT)	50.00
Ammonium nitrate	50.00
Water	NA[a]
C-4 donor charge	NA
Polyethylene bag	NA

[a]Not applicable (items were used to support the test setup).

Table 2.10. Nominal Composition of Material Used in the Diesel Fuel and Dunnage Burning Trials.

Ingredient	Mass (%)
Cellulose	87.46
Plastic and Oil	12.54
Ignitor[a]	NA[b]

[a]Hercules Unique™ smokeless powder.

[b]Not applicable (item used to support the test setup).

Table 2.11. Mass of Energetic Material (MEM) of the Test Items.

Item	MEM per Item (g)	Donor Charge[a] (g)	Blasting Cap (g)	Total Trial MEM (g)
Detonating cord	203	NA[b]	0.0054	203.01
Tritonal Surrogate (Trials 1 and 2)	227	NA	0.0054	227.01
Tritonal Surrogate (Trial 3)	227	6.5	0.0054	233.51
Tritonal Surrogate with Calcium Stearate	227	6.5	0.0054	233.51
Amatol Surrogate	227	6.5	0.0054	233.51
Composition B Surrogate	227	6.5	0.0054	233.51
Composition B Surrogate with Aluminum (HBX)	227	6.5	0.0054	233.51
Tritonal Surrogate Surrounded by Water	227	6.5	0.0054	233.51
Manufacturer's Waste	1135[c]	4.0	NA	1139.00
Amatol Surrogate Surrounded by Water	227	6.5	0.0054	233.51
Diesel Fuel and Dunnage	909[c]	4.0	NA	913.00

[a]Unless otherwise state, donor charge was composition C-4 explosive.

[b]Not applicable.

[c]Mass includes material contaminated with energetic material and other components.

Table 2.12. Test Matrix.

Date 1995	Time (MDT[a])	Test Item	Supplemental Items
15 Aug 95	1215	Detonating cord	One M6 blasting cap
15 Aug 95	1357		One M6 blasting cap
15 Aug 95	1534		One M6 blasting cap
16 Aug 95	1047	Tritonal surrogate	One M6 blasting cap
16 Aug 95	1424		One M6 blasting cap
16 Aug 95	1610		One M6 blasting cap, 6.5-g composition C-4
17 Aug 95	1010	Tritonal surrogate with calcium stearate	One M6 blasting cap, 6.5-g composition C-4
17 Aug 95	1435		One M6 blasting cap, 6.5-g composition C-4
17 Aug 95	1606		One M6 blasting cap, 6.5-g composition C-4
18 Aug 95	1028	Amatol surrogate	One M6 blasting cap, 6.5-g composition C-4
18 Aug 95	1212		One M6 blasting cap, 6.5-g composition C-4
18 Aug 95	1339		One M6 blasting cap, 6.5-g composition C-4
19 Aug 95	1015	Composition B surrogate	One M6 blasting cap, 6.5-g composition C-4
19 Aug 95	1137		One M6 blasting cap, 6.5-g composition C-4
19 Aug 95	1417		One M6 blasting cap, 6.5-g composition C-4
21 Aug 95	1108	Composition B surrogate with aluminum (HBX)	One M6 blasting cap, 6.5-g composition C-4
21 Aug 95	1336		One M6 blasting cap, 6.5-g composition C-4
21 Aug 95	1540		One M6 blasting cap, 6.5-g composition C-4
22 Aug 95	1035	Tritonal surrogate with water	One M6 blasting cap, 6.5-g composition C-4
22 Aug 95	1225		One M6 blasting cap, 6.5-g composition C-4
22 Aug 95	1418		One M6 blasting cap, 6.5-g composition C-4
23 Aug 95	1320	Manufacturer's waste (aluminized AP[b], plastic, paper, cloth, wood, diesel fuel)	4-g Hercules Unique™ smokeless powder
24 Aug 95	1038		4-g Hercules Unique™ smokeless powder
25 Aug 95	1037		4-g Hercules Unique™ smokeless powder
28 Aug 95	1009	Amatol surrogate with water	One M6 blasting cap, 6.5-g composition C-4
28 Aug 95	1150		One M6 blasting cap, 6.5-g composition C-4
28 Aug 95	1326		One M6 blasting cap, 6.5-g composition C-4
29 Aug 95	1116	Diesel fuel and dunnage	4-g Hercules Unique™ smokeless powder
30 Aug 95	1056		4-g Hercules Unique™ smokeless powder
30 Aug 95	1247		4-g Hercules Unique™ smokeless powder

[a]Mountain daylight time.
[b]Ammonium perchlorate.

SECTION 3. TEST METHODOLOGY

3.1 OVERVIEW

The development of the BangBox testing facility at DPG was based on a series of tests conducted in other facilities and in open-air (References 4 and 5). Emissions collected and assayed during those tests provided the framework for the instrumentation and sampling strategies now used in the BangBox facility. The BangBox facility allows the quantity of target analytes generated from the burning or detonation of the test items to be determined. This information is used to calculate emission factors (the ratio of the mass of target analyte generated to the mass of energetic material of the PEP item burned or detonated) for the item tested. Results from BangBox testing can be scaled to provide emissions data for OB/OD treatment of materials several times the quantities tested in the facility.

3.1.1 BangBox Test Facility

The BangBox test facility consists of the BangBox test chamber with attached airlock, a data acquisition system (DAS), a command post (CP), a munitions preparation trailer, and a portable munitions storage magazine.

3.1.1.1 BangBox Test Chamber

a. The BangBox test chamber sits on a concrete pad and is constructed of flexible polyvinylchloride (PVC)-coated polyester fabric in the shape of a 16-m diameter hemisphere. The test chamber is kept inflated at a volume of approximately 950 m^3 by two high-capacity blowers that inject ambient air into the chamber. The test chamber serves to capture the cloud from burning or detonation of test items. Large fans circulate the air in the chamber to produce a homogenous cloud that is sampled by instruments positioned in the chamber and attached airlock.

b. The airlock is constructed of plywood and is attached to the side of the test chamber. It houses instruments and equipment and serves to minimize the pressure loss through the passageway to the test chamber. The test chamber entryway contains a weighted overpressure hatch that protects the BangBox structure in the event of rapid overpressure caused by the burning or detonation of test items.

c. Test items to be burned are contained in stainless steel burn pans placed on a 1-m^2 steel plate burn pad located in the center of the test chamber. For items to be detonated, the burn pad is removed, and the item is placed in the detonation chamber which lies below the burn pad. After the completion of each trial, the test chamber is thoroughly cleaned and the air is evacuated.

3.1.1.2 Data Acquisition System (DAS). The DAS consists of five computers connected to a local area network (LAN). Two of the computers are located in the BangBox airlock; they provide data and video input to the LAN. The remaining computers are located in the CP, and they display or store data generated in the BangBox. The primary software used to collect and assemble raw data during this test was Lab Tech Notebook™ version 8.03 for Windows®.

3.1.1.3 Command Post (CP). The CP is located approximately 500 meters from the BangBox and contains a DAS file server, remote DAS monitors, detonation/ignition firing system (DIFS) station, closed-circuit television monitor (connected to the chamber camera), radio communication system, and a small work station for conducting test support.

3.1.1.4 Munitions Preparation Trailer. The munitions preparation trailer is used to weigh test items and prepare them for burning or detonation in the BangBox test chamber.

3.1.1.5 Portable Munitions Storage Magazine. A portable munitions storage magazine provides a means of temporarily storing small quantities of energetic test items and materials before testing.

3.2 TARGET ANALYTES

The cloud generated from the OB/OD treatment of test items was sampled for target inorganic gases, volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), metals, and, for some items, dioxins, furans, HCl, and Cl_2. The following sections list the target analytes by group. The VOCs included nonmethane organic compounds (NMOCs), groups of compounds based on chemical structure, and a 42-component list of air toxics listed by the EPA.

3.2.1 Target Inorganic Gases

CO_2, CO, NO_x (NO and NO_2), SO_2, O_3, and SF_6 (released as a tracer during each test trial).

3.2.2 Volatile Organic Compounds (VOCs)

Alkanes (Paraffins)

n-Heptane
2,4-Dimethylhexane
2-Methylheptane
2-Methylpentane
3-Methylpentane
Ethylcyclohexane
n-Hexane
i-Butane
Methylcyclopentane
n-Butane
2,4-Dimethylpentane
2,2-Dimethylpropane
Cyclohexane
n-Pentane
2,3-Dimethylpentane
Cyclopentane
3-Ethylhexane,3-Methylheptane
n-Octane
Ethane
2,3-Dimethylhexane
i-Pentane
Methane
2,2,4-Trimethylpentane
Methylcyclohexane
2,3,4-Trimethylpentane
n-Nonane
2,3-Dimethylbutane
Propane
2,2-Dimethylbutane
3-Methylhexane
2-Methylhexane
2,5-Dimethylhexane
2,2-Dimethylheptane
2,2,4-Trimethylhexane
n-Decane

Alkenes (Olefins)

Ethylene
2-Methyl-1-pentene
Propene
1-Butene
i-Butene
trans-2-Hexene
3-Methyl-1-butene
Isoprene
1,3-Butadiene
trans-2-Pentene
cis-2-Butene
cis-2-Hexene
1-Pentene
2-Methyl-2-butene

Alkenes (Olefins) (Cont'd)

1-Hexene
4-Methyl-1-pentene
trans-2-Butene
2-Methyl-2-pentene
2-Methyl-1-butene
Cyclopentene
cis-2-Pentene
cis-4-Methyl-2-pentene
2,4,4-Trimethyl-1-pentene
2,4,4-Trimethyl-2-pentene

Aromatics

Toluene
1,3,5-Trimethylbenzene
n-Propylbenzene
Styrene
i-Propylbenzene
Ethylbenzene
o-Xylene
m-, p-Xylene
1,2,4-Trimethylbenzene & sec-butylbenzene
Benzene
p-Ethyltoluene
m-Ethyltoluene
o-Ethyltoluene

Others

Acetylene
Nonmethane organic compounds (NMOCs)
Total unidentified hydrocarbons

3.2.3 Volatile Organic Compounds (VOCs) (42-Component List)

Freon® 12
Methyl chloride
Freon® 114
Vinyl chloride
1,3-Butadiene
Methyl bromide
Ethyl chloride
Freon® 11
Vinylidene chloride
Dichloromethane
Allyl chloride
Freon® 113
1,1-Dichloroethane
cis-1,2-Dichloroethylene
Chloroform
1,2-Dichloroethane
Methyl chloroform
Benzene
Carbon tetrachloride
1,2-Dichloropropane
Trichloroethylene
cis-1,3-Dichloropropene
trans-1,3-Dichloropropene
1,1,2-Trichloroethane
Toluene
1,2-Dibromoethane
Tetrachloroethylene
Chlorobenzene
Ethylbenzene
m-, p-Xylene
Styrene
1,1,2,2-Tetrachloroethane
o-Xylene
p-Ethyltoluene
1,3,5-Trimethylbenzene
1,2,4-Trimethylbenzene
Benzyl chloride
m-Dichlorobenzene
p-Dichlorobenzene
o-Dichlorobenzene
1,2,4-Trichlorobenzene
Hexachlorobutadiene

3.2.4 Semivolatile Organic Compounds (SVOCs)

Phenol
bis(2-Chloroethyl)ether
2-Chlorophenol
1,3- Dichlorobenzene
1,4-Dichlorobenzene
Benzyl alcohol
1,2-Dichlorobenzene
2-Methylphenol (o-Cresol)
bis(2-Chloro-1-isopropyl)ether
3- and 4-Methylphenol (m- and p-Cresol)
Pentachloroethane
N-Nitrosodi-N-propylamine
Hexachloroethane
Pyridine
N-Nitrosodimethylamine
2-Picoline
N-Nitrosomethylethylamine
Methyl methanesulfonate
N-Nitrosodiethylamine
Ethyl methanesulfonate
Aniline
N-Nitrosopyrrolidine
Acetophenone
N-Nitrosomorpholine
o-Toluidine
Nitrobenzene
Isophorone
2,4-Dimethylphenol
2-Nitrophenol
bis(2-Chloroethoxy)methane
2,4-Dichlorophenol
1,2,4-Trichlorobenzene
Naphthalene
4-Chloroaniline
Hexachloro-1,3-butadiene
4-Chloro-3-methylphenol
2-Methylnaphthalene
N-Nitrosopiperidine
o,o,o-Triethylphosphorothioate
2,4-Dichlorophenol
Hexachloropropene
2,6-Dichlorophenol
1,4-Phenylenediamine
N-Nitrosodi-N-butylamine
Hexachlorocyclopentadiene
2,4,6-Trichlorophenol
2,4,5-Trichlorophenol
2-Chloronaphthalene
2-Nitroaniline
Dimethyl phthalate
2,6-Dinitrotoluene
Acenaphthylene
3-Nitroaniline
2,4-Dinitrophenol
Acenaphthene
4-Nitrophenol
2,3-Dinitrotoluene
Dibenzofuran
Diethyl phthalate
4-Chlorophenyl-phenyl ether
Fluorene
4-Nitroaniline
1,2,4,5-Tetrachlorobenzene
Isosafrole
Safrole
1,4-Naphthoquinone
1,3-Dinitrobenzene
Pentachlorobenzene
1-Naphthylamine
2,3,4,6-Tetrachlorophenol
2-Naphthylamine
Thionazin
5-Nitro-o-toluidine
4,6-Dinitro-2-methylphenol
N-Nitrosodiphenylamine
4-Bromophenyl-phenyl ether
Hexachlorobenzene
Pentachlorophenol
Phenanthrene
Anthracene
Di-n-butyl phthalate
Fluoranthene
Tetraethyl dithiopyrophosphate
1,3,5-Trinitrobenzene
cis-Diallate
trans-Diallate
Pronamide
4-Nitroquinoline-1-oxide
Methapyrilene
Isodrin
Pyrene
Butylbenzyl phthalate
bis(2-Ethylhexyl) phthalate
3,3'-Dichlorobenzidine
Benzo(a)anthracene
Chrysene
p-(Dimethylamino)azobenzene
Chlorobenziliate
a,a-Dimethylphenethylamine

Semivolatile Organic Compounds (SVOCs) (Cont'd)

3,3'-Dimethylbenzidine
2-Acetylaminofluorene
Di-n-octyl phthalate
Benzo(b)fluoranthene
Benzo(k)fluoranthene
Benzo(a)pyrene
Indeno(1,2,3-cd)pyrene
Dibenz(a,h)anthracene
Benzo(ghi)perylene
7,12-Dimethylbenz(a)anthracene
Hexachlorophene
Dimethoate
Phenacetin
4-Aminobiphenyl
Pentachloronitrobenzene

3.2.5 Metals

Aluminum
Antimony
Arsenic
Barium
Cadmium
Calcium
Chromium
Copper
Lead
Mercury
Nickel
Potassium
Sodium
Titanium
Zinc

3.2.6 Particulate Matter Less Than Ten Microns in Diameter (PM_{10})

3.2.7 Dioxins and Furans

The analysis for dioxins and furans included total tetrachlorinated dibenzo-*p*-dioxin (TCDD), total pentachlorinated dibenzo-*p*-dioxin (PeCDD), total hexachlorinated dibenzo-*p*-dioxin (HxCDD), total heptachlorinated dibenzo-*p*-dioxin (HpCDD), octachlorinated dibenzo-*p*-dioxin (OCDD), 2378-TCDD, 1234678-HpCDD, total tetrachlorinated dibenzofuran (TCDF), total pentachlorinated dibenzofuran (PeCDF), total hexachlorinated dibenzofuran (HxCDF), total heptachlorinated dibenzofuran (HpCDF), octachlorinated dibenzofuran (OCDF), 2378-TCDF, 12378-PeCDF, 23478-PeCDF, 123478-HxCDF, 123678-HxCDF, 234678-HxCDF, 1234678-HpCDF, and 1234789-HpCDF. The manufacturer's waste and the diesel fuel and dunnage burns were sampled for dioxins and furans.

3.2.8 Percent Chlorine Recovered as HCl and Cl_2

Samples were collected to measure HCl and Cl_2 concentrations to determine the percent chlorine recovered as HCl and Cl_2 during the manufacturer's waste trials.

3.3 SAMPLING AND ASSAYING METHODS

3.3.1 Target Inorganic Gases

a. Concentrations of CO_2, CO, NO_x (NO and NO_2) O_3, SO_2, and SF_6 were measured using real-time gas analyzers. The analyzers were designed for continuous operation and provided real-time voltage data to the DAS for recording. The analyzers were operated from approximately 10 minutes before burn/detonation initiation to approximately 35 minutes after burn/detonation initiation. Calibration of the analyzers followed manufacturer's procedures and instructions provided by EPA quality assurance/quality control audit personnel.

b. Samples for measurement of CO_2 and CO were also collected using evacuated 6-L stainless steel SUMMA® canisters in accordance with (IAW) EPA Compendium TO-14 method. The samples were assayed using gas chromatography (GC)/flame ionization detection (FID) IAW EPA Compendium TO-14 method. Samples were collected from approximately 5 minutes after burn/detonation initiation to approximately 6.5 minutes after burn/detonation initiation.

c. Samples for measurement of SF_6 were collected using evacuated 0.85-L stainless steel SUMMA® canisters IAW EPA Compendium TO-14 method. The samples were assayed using a special GC/electron capture detection (ECD) method IAW EPA Compendium TO-14 method. The SF_6 was used as a tracer to determine the volume of the BangBox test chamber and the dilution rate of target analytes because of maintenance of chamber pressure (Section 4). The SF_6 was released during each trial using a pressurized (approximately 10 atm) 0.85-L SUMMA® canister containing SF_6 at a concentration that would give an initial concentration of SF_6 in the BangBox test chamber of 500 parts per million volume (ppmv). The canister was placed on the floor near the center of the chamber and opened at the time of burn/detonation initiation. Samples were collected at approximately 5, 7, 11, 19, and 35 minutes after release.

d. The real-time analyzers and SUMMA® canisters were located in the BangBox airlock and sampled the test chamber air through a stainless steel sampling manifold that extended into the test chamber.

3.3.2 Volatile Organic Compounds (VOCs)

a. Samples for measurement of VOCs were collected using evacuated 6-L stainless steel SUMMA® canisters IAW EPA Compendium TO-12 or TO-14 method. Samples were collected from approximately 5 minutes after burn/detonation initiation to approximately 6.5 minutes after burn/detonation initiation.

b. The samples were assayed for NMOCs using GC/FID IAW EPA Method TO-12, groups of VOCs using GC/FID IAW EPA Method TO-14, and 42-component list of VOCs using GC/mass spectrometry (MS) IAW EPA Compendium TO-14 method.

c. The SUMMA® canisters were located in the BangBox airlock and sampled the test chamber air through a stainless steel sampling manifold that extended into the test chamber.

3.3.3 Semivolatile Organic Compounds (SVOCs)

a. Samples for measurement of SVOCs were collected using high-volume total suspended particulate (TSP) air samplers equipped with quartz-fiber filters; pesticide sampler (PS)-1 air samplers equipped with quartz-fiber filters followed by a borosilicate glass cartridge containing XAD-2® resin; and high-volume particulate matter less than ten microns in diameter (PM_{10}) air samplers equipped with quartz-fiber filters. The samplers were operated from approximately 15 minutes before burn/detonation initiation to approximately 35 minutes after burn/detonation initiation. The filter extracts were assayed for SVOCs using GC/MS IAW EPA Method 8270.

b. Each of the samplers had a flow rate monitor connected to the DAS. The DAS recorded voltages every second which were converted to flow rates (m^3/min) using a reference flow orifice.

c. The samplers were located in the BangBox test chamber and sampled the test chamber air directly.

3.3.4 Metals

a. Samples for measurement of metals were collected using high-volume TSP air samplers equipped with quartz-fiber filters and PM_{10} samplers equipped with quartz-fiber filters. The samplers were operated from approximately 15 minutes before burn/detonation initiation to approximately 35 minutes after burn/detonation initiation. The filter extracts were assayed for metals using inductively coupled plasma (ICP)/optical emission spectrometry (OES) IAW EPA SW-846, Methods 3050A and 6010A and cold vapor atomic absorption (CVAA) IAW EPA SW-846, Methods 3050A and 7471.

b. Each of the samplers had a flow rate monitor connected to the DAS. The DAS recorded voltages every second which were converted to flow rates (m^3/min) using a reference flow orifice.

c. The samplers were located in the BangBox test chamber and sampled the test chamber air directly.

3.3.5 Particulate Matter Less Than Ten Microns in Diameter (PM_{10})

a. Samples for measurement of PM_{10} were collected using a PM_{10} size selective high-volume sampler. The sampler was operated from approximately 15 minutes before burn/detonation initiation to approximately 35 minutes after burn/detonation initiation.

b. The sampler had a flow rate monitor connected to the DAS. The DAS recorded voltages every second which were converted to flow rates (m^3/min).

c. The sampler was located in the BangBox test chamber and sampled the chamber air directly.

3.3.6 Dioxins and Furans

a. Samples for measurement of dioxins and furans were collected using a PS-1 air sampler equipped with a quartz-fiber filter followed by a borosilicate glass cartridge containing XAD-2® resin. The sampler was operated from approximately 15 minutes before burn/detonation initiation to approximately 35 minutes after burn/detonation initiation. The filter extracts were assayed for dioxins and furans using GC/MS IAW EPA Method 8290X.

b. The sampler had a flow rate monitor connected to the DAS. The DAS recorded voltages every second which were converted to flow rates (m^3/min) using a reference flow orifice.

c. The samplers were located in the BangBox test chamber and sampled the test chamber air directly.

3.3.7 Percent Chlorine Recovered as HCl and Cl_2

a. Samples for measurement of HCl and Cl_2 were collected using six 30-ml dual train midget impingers to determine the percent chlorine recovered as HCl and Cl_2. The impingers were operated from burn/detonation initiation to approximately 35 minutes after burn/detonation initiation. The extracts were assayed for HCl and Cl_2 IAW EPA Method 26.

b. The impingers were located in the BangBox test chamber and sampled the test chamber air directly.

3.3.8 Sampling and Assaying Summary

a. The types of samplers and assay methods used to measure the concentrations of the target analytes are summarized in Table 3.1.

b. The letter(s) of instruction (LOI) for the sampling procedures and laboratory results are available through WDTC upon request.

Table 3.1. Samplers and Assay Methods Used to Measure Concentrations of Target Analytes.

Analyte[a]	Sampler[b]	Sampler Location	Sampling Procedure[c]	Assay Method[d]
CO_2, CO, NO_x, O_3 and SO_2	Real-time analyzers	BangBox airlock	WDTC LOI	Calibrated voltage data
CO_2 and CO	6-L SUMMA® canisters	BangBox airlock	OGI LOI	GC/FID, EPA Method TO-14
SF_6	0.85-L SUMMA® canister	BangBox airlock	OGI LOI	GC/ECD, EPA Method TO-14
VOCs (NMOCs)	6-L SUMMA® canisters	BangBox airlock	OGI LOI	GC/FID, EPA Method TO-12
VOCs (groups based on structure)	6-L SUMMA® canisters	BangBox airlock	OGI LOI	GC/FID, EPA Method TO-14
VOCs (42-component list)	6-L SUMMA® canisters	BangBox airlock	OGI LOI	GC/MS, EPA Method TO-14
SVOCs	High-volume TSP, PS-1, and PM_{10} samplers	BangBox test chamber	MSAI LOI and Radian Corp. LOI	GC/MS, EPA Method 8270
Metals	High-volume and PM_{10} samplers	BangBox test chamber	MSAI LOI	ICP/OES and CVAA, EPA SW-846 Methods 3050A and 7471
PM_{10}	PM_{10}	BangBox test chamber	MSAI LOI	Mass determination
Dioxins and Furans	PS-1 sampler	BangBox test chamber	Radian Corp. LOI	GC/MS, EPA Method 8290X
HCl and Cl_2	30-ml dual train midget impingers	BangBox test chamber	Radian Corp. LOI	EPA Method 26

[a]VOCs - volatile organic compounds; NMOCs - nonmethane organic compounds; SVOCs - semivolatile organic compounds; and PM_{10} - particulate matter less than ten microns in diameter.

[b]TSP - total suspended particulate; and PS - pesticide sampler.

[c]WDTC - West Desert Test Center; LOI - letter(s) of instruction; OGI- Oregon Graduate Institute of Science and Technology; and MSAI - Mountain States Analytical, Inc.

[d]GC/FID - gas chromatography/flame ionization detection; EPA - U.S. Environmental Protection Agency; GC/ECD - gas chromatography/electron capture detection; GC/MS - gas chromatography/mass spectrometry; ICP/OES - inductively coupled plasma/optical emission spectrometry; and CVAA - cold vapor atomic absorption.

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SECTION 4. ANALYTICAL METHODS

4.1 OBJECTIVES

a. Determine a composite exponential rate of change to apply to measured concentrations of target chemical species, when applicable, to account for the following sources of sample dilution:

(1) Addition of ambient air into the chamber to maintain chamber inflation.

(2) Flow reduction in each high-volume, PS-1, and PM_{10} sampler.

(3) Addition of filtered air from the continuous flow samplers into the chamber.

b. Determine the instantaneous concentrations of target chemical species generated by the burn or detonation of test items.

c. Determine the volume of the BangBox test chamber during each test trial.

d. Correct sampler flow rates and calculated BangBox chamber volumes to standard temperature and pressure (STP).

e. Determine emission factors for target chemical species of material being tested.

f. Determine the percent chlorine recovered as HCl and Cl_2.

4.2 DATA REQUIRED

a. The concentration of SF_6 tracer gas released into the chamber and the concentration of SF_6 tracer gas measured at designated time intervals during the test.

b. Flow rates for continuous flow samplers over the sampling period.

c. Background concentrations of target chemical species in the BangBox chamber.

d. Temperature and barometric pressure measurements of the chamber during the test.

e. Concentrations of target chemical species resulting from burning or detonation of the test item.

f. Mass of chlorine burned or detonated and measured concentrations of HCl and Cl_2.

4.3 DATA ANALYSES

a. Composite exponential rate of change to apply to measured concentrations of target chemical species to account for sources of sample dilution.

(1) Correction for Dilution Because of Chamber Pressure Maintenance. The SF_6 concentration data collected during the test were used to model the dilution rate within the chamber because of maintenance of chamber pressure. The data were fit to an exponential model (Equation 4.1), using the method of least squares, to determine the dilution rate from the inflation system. An example of the actual data and model from a trial are shown in Figure 4.1.

$$C(t) = C(0)\ e^{k_1 t}$$ Equation 4.1

where C(t) = concentration of target chemical species at time = t
t = time from burn/detonation initiation or tracer release
C(0) = concentration of target chemical species at t = 0
k_1 = exponential rate of change per unit of time due to air added to BangBox to keep the chamber inflated

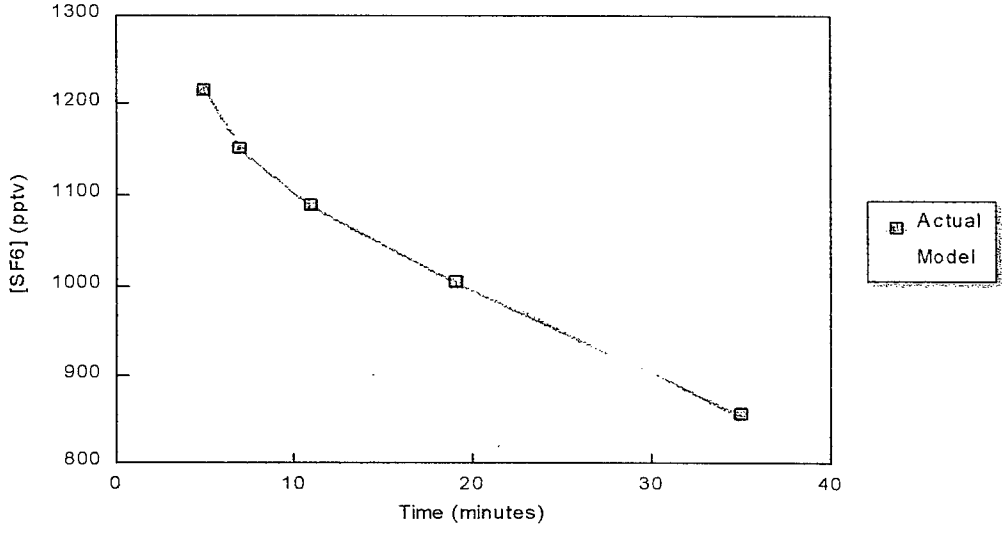

Figure 4.1. Concentration of SF_6 Tracer Gas Versus Time.

(2) Correction for Reduction of Flow in Individual High-volume, PS-1, and PM_{10} Samplers During the Sampling Period. The collection of chemical species and particulate matter on the filters of the high-volume, PS-1, and PM_{10} samplers results in a decrease in sampler flow rate over the sampling period. An exponential model (Equation 4.2) was fit to the individual sampler flow rate over time using the method of least squares to model the flow rate reduction occurring in individual high-volume, PS-1, and PM_{10} samplers over the sampling period (Figure 4.2). When filters from individual samplers were combined for laboratory analysis and the results were reported as mass/number of filters, the flow rates of the individual samplers were summed for each second and the resulting combined flow rate was fit to an exponential model using the method of least squares.

$$F(t) = F(0)\ e^{k_2 t}$$ Equation 4.2

where F(t) = flow rate of individual sampler at time = t
t = time from burn/detonation initiation
F(0) = flow rate of individual sampler at t = 0
k_2 = exponential rate of change per unit of time due to reduction in individual (or combined) sampler flow rate

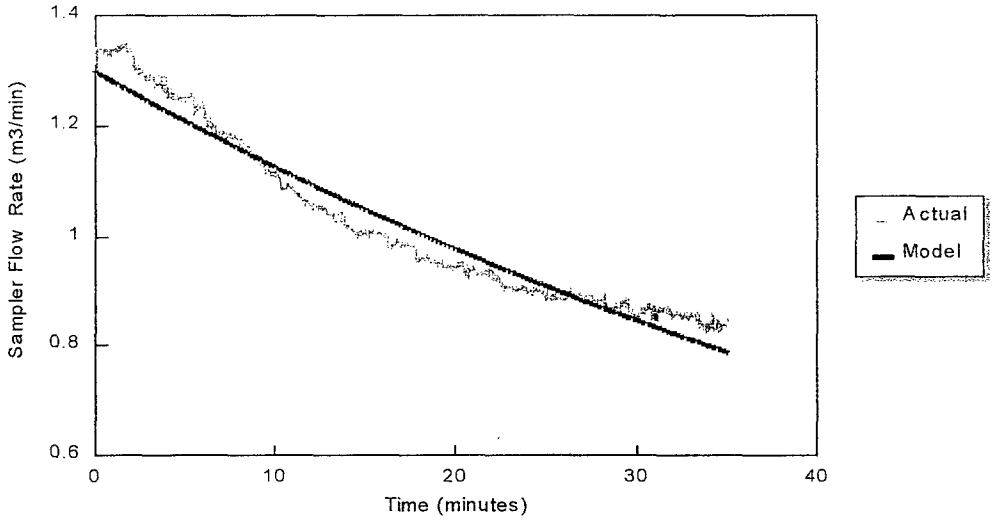

Figure 4.2. Sampler Flow Rate Versus Time.

(3) Correction For Dilution Because of Addition of Filtered Air From All High-volume, PS-1, and PM_{10} Samplers in the Chamber. The flow rate data for the high-volume, PS-1, and PM_{10} samplers were summed for each second from burn/detonation initiation to the end of the sampling period. An exponential model (Equation 4.3) was fit to these data using the method of least squares to determine the dilution rate of measured concentrations because of the addition of filtered air from the samplers. An example of the actual data and model from a trial are shown in Figure 4.3.

$$\sum F(t) = \sum F(0)\ e^{k_3 t}$$ Equation 4.3

where $\Sigma F(t)$ = sum of flow rates for all high-volume, PS-1, and PM_{10} samplers at time = t
t = time from burn/detonation initiation
$\Sigma F(0)$ = sum of flow rates for all high-volume, PS-1, and PM_{10} samplers at time = 0
k_3 = exponential rate of change per unit of time due to addition of filtered air from all high-volume, PS-1, and PM_{10} samplers in the chamber

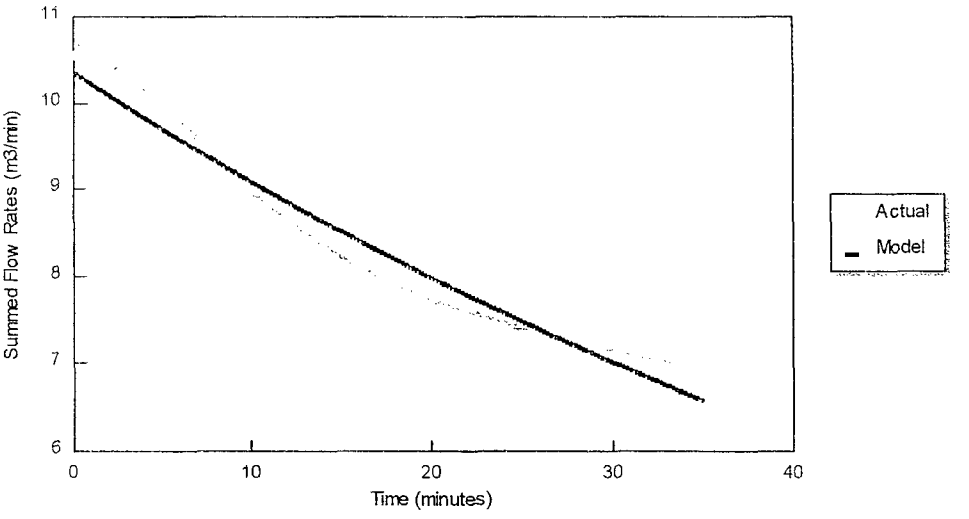

Figure 4.3. Summed Flow Rates For All Samplers Versus Time.

(4) The Composite Exponential Rate of Change. The composite exponential rate of change for a target chemical species depends on its sources of sample dilution. For instance, all measured concentrations of chemical species have been diluted by chamber ventilation, but not all have been diluted by flow reduction in the samplers or the addition of filtered air from the samplers (i.e., inorganic gases). The following relationship (Equation 4.4) shows how individual exponential rates of change from Equations 4.1, 4.2, and 4.3 can be combined to determine a composite model for a chemical species whose measured sample concentration has been diluted from all three dilution sources. The measured concentration is a function of all three dilution sources and the equations used to model them individually can be combined to characterize the concentration over time. Table 4.1 summarizes the exponential rates of change used to model the different classes of compounds for their sources of dilution based on the type of samplers used to collect and measure them.

$$\begin{aligned} C_S(t) &= C_S(0)\left(e^{k_1 t} * e^{k_2 t} * e^{k_3 t}\right) \\ &= C_S(0)\, e^{(k_1 + k_2 + k_3)t} \\ &= C_S(0)\, e^{k_C t} \end{aligned} \qquad \text{Equation 4.4}$$

where $C_S(t)$ = concentration of target chemical species at time = t
t = time after burn/detonation initiation or tracer release
$C_S(0)$ = undiluted (corrected) concentration of target chemical species
k_1 = exponential rate of change per unit of time because of air added to BangBox to keep chamber inflated
k_2 = exponential rate of change per unit of time due to reduction in sampler flow rate
k_3 = exponential rate of change per unit of time due to addition of filtered air from the continuous samplers into the chamber
k_C = composite exponential rate of change per unit time due to all three dilution sources ($= k_1 + k_2 + k_3$)

Table 4.1. Composite Exponential Rates of Change Used to Model Classes of Compounds.

Class of Compound	Type of Sampler Used	Composite Exponential Rate of Change (k_c)
Target inorganic gases	Real-time analyzer and SUMMA® canister	NA[a]
VOCs[b]	SUMMA® canister	k_1
SVOCs[c]	High-volume, PS[d]-1, and PM_{10}[e]	$k_1 + k_2 + k_3$
Metals	High-volume and PM_{10}	$k_1 + k_2 + k_3$
PM_{10}	PM_{10} sampler	$k_1 + k_2 + k_3$
Dioxins and Furans	PS-1	$k_1 + k_2 + k_3$
HCl and Cl_2	Dual train impinger	$k_1 + k_2$

[a]Not applicable (see Paragraphs 4.3.c and 4.3.e).
[b]Volatile organic compounds.
[c]Semivolatile organic compounds.
[d]Pesticide sampler.
[e]Particulate matter less than ten microns in diameter.

b. The time average concentration of target chemical species collected over time (t_1 to t_2) can be expressed as:

$$\bar{C}_S = \frac{\int_{t_1}^{t_2} C_S(0)\ e^{k_C t}\ dt}{t_2 - t_1} \qquad \text{Equation 4.5}$$

where $\bar{C}_S$ = average concentration of target chemical species
$C_S(0)$ = undiluted (instantaneous) concentration of target chemical species
k_c = composite exponential rate of change per unit time (Table 4.1)

Integrating equation 4.5 over the interval t_1 to t_2 yields:

$$\bar{C}_S = \frac{C_S(0)}{k_C} * \frac{e^{k_C t_2} - e^{k_C t_1}}{t_2 - t_1} \qquad \text{Equation 4.6}$$

and rearranging terms yields:

$$C_S(0) = \frac{k_c * (t_2 - t_1)}{e^{k_C t_2} - e^{k_C t_1}} * \bar{C}_S \qquad \text{Equation 4.7}$$

where the correction factor (CF) to account for dilution sources is

$$CF = \frac{k_c * (t_2 - t_1)}{e^{k_C t_2} - e^{k_C t_1}} \qquad \text{Equation 4.8}$$

and the average concentration (corrected for volume sampled prior to burn/detonation initiation and background concentration) is

$$\bar{C}_S = \frac{M_{S_{trial}} - \left(\frac{M_{S_{bkgd}}}{V_{S_{bgkd}}} * V_{S_{b4db}} \right)}{V_{S_{trial}}} - \frac{M_{S_{bkgd}}}{V_{S_{bgkd}}} \qquad \text{Equation 4.9}$$

where M_{Strial} = measured mass of target chemical species during trial
V_{Strial} = volume of air sampled to collect mass of target chemical species during trial
M_{Sbkgd} = measured mass of target chemical species before trial
V_{Sbkgd} = volume of air sampled to collect mass of target chemical species before trial
V_{Sb4bd} = volume of air sampled before burn/detonation initiation.

The volumes sampled by individual samplers were estimated using numerical integration of the recorded flow rate data.

c. The instantaneous concentrations of target inorganic gases emitted were determined by fitting an exponential model [$C(t) = C(0)\, e^{kt}$] to the real-time analyzer data, corrected for background concentrations, and extrapolating to burn/detonation initiation time ($t = 0$) (Figure 4.4). This concentration (measured as ppmv) was used along with the equation of state for an ideal gas (Equation 4.10) to determine the mass of target inorganic gas emitted.

$$P\, V_{gas} = n\, R\, T \qquad \text{Equation 4.10}$$

where P = pressure of the gas (expressed as atm)
V_{gas} = volume of the gas
n = number of moles of gas
R = the universal gas constant = 0.0821 L atm/mol K
T = temperature of the gas (expressed as K)

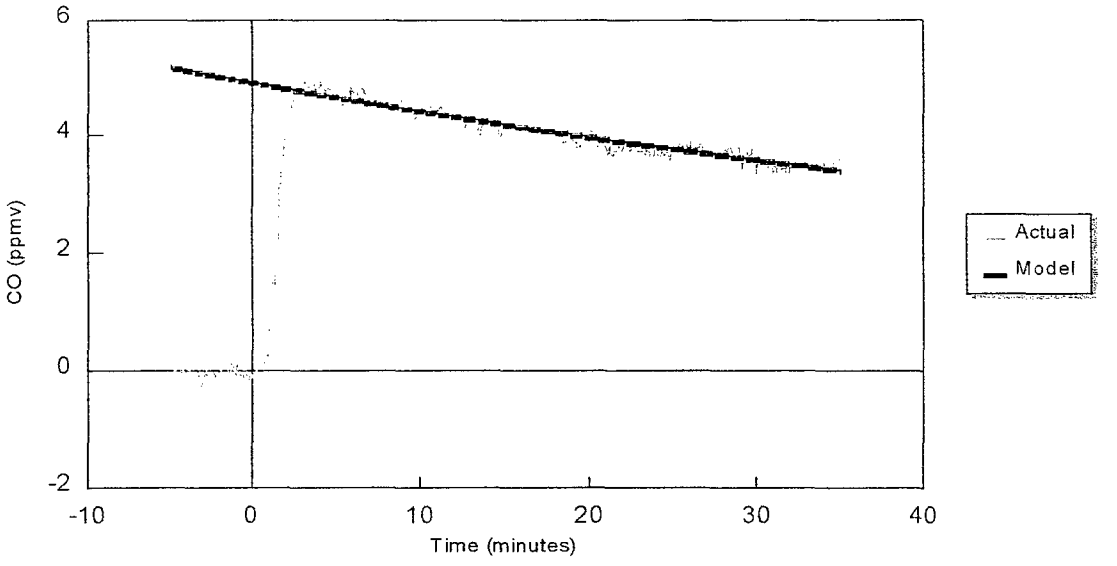

Figure 4.4. Concentration of a Target Inorganic Gas (CO) Versus Time.

The volume of the gas is related to its concentration (measured as ppmv) and the volume of the BangBox chamber (V_{BB}) through the expression

$$V_{gas} = ppmv * V_{BB} \qquad \text{Equation 4.11}$$

and the number of moles of gas is related to its mass (m) and its molecular weight (MW) through the expression

$$n = \frac{m}{MW} \qquad \text{Equation 4.12}$$

Substituting these expressions into Equation 4.10 and rearranging terms yields the following expression for the mass of target inorganic gas emitted:

$$m = \frac{P * ppmv * V_{BB} * MW}{R * T} \qquad \text{Equation 4.13}$$

d. BangBox chamber volume

(1) The SF_6 concentration data were used to estimate the volume of the chamber using the following relationship:

$$V_{BB} = \frac{C_{gas} * V_{gas}}{C_{BB}}$$ Equation 4.14

where V_{BB} = BangBox chamber volume
C_{gas} = concentration of SF_6 gas in canister before release
V_{gas} = volume of SF_6 gas in canister before release
C_{BB} = corrected concentration of SF_6 gas in chamber after release

(2) The concentration of SF_6 tracer gas in the test chamber after release was corrected using Equation 4.1. The calculated chamber volumes were adjusted to STP (25°C and 760 mm Hg).

e. Emission factors for all target chemical species (excluding inorganic gases) were calculated using the following relationship:

$$EF_S = \frac{C_S(0) * V_{BB}}{MEM}$$ Equation 4.15

where EF_S = emission factor for target chemical species
$C_S(0)$ = corrected concentration of target chemical species (using Equation 4.7)
V_{BB} = BangBox chamber volume
MEM = mass of energetic material

Emission factors for target inorganic gases were calculated using the following relationship:

$$EF_g = \frac{m}{MEM}$$ Equaton 4.16

where EF_g = emission factor for target inorganic gas
m = mass of target inorganic gas (using Equation 4.13)
MEM = mass of energetic material

The mass of target inorganic gas was not corrected for sources of dilution because it was assumed that any source of dilution, including ventilation of the BangBox chamber, would be corrected for when the real-time analyzer data were extrapolated to determine the instantaneous gas concentrations.

f. The percent chlorine recovered as HCl and Cl_2 was determined using the following relationship:

$$\%\ Chlorine\ Recovered = \frac{M_{Chlorine}\ Emitted}{M_{Chlorine}\ Initial} * 100 \qquad \text{Equation 4.17}$$

where $M_{Chlorine}$ Emitted = mass of chlorine emitted as HCl or Cl_2
$M_{Chlorine}$ Initial = mass of chlorine in test item prior to burn/detonation

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SECTION 5. RESULTS

5.1 RESULTS FROM SF_6 TRACER GAS

The results from the SF_6 tracer gas used for each trial to determine the volume of the BangBox test chamber and the exponential rate of change of target analyte concentrations from maintenance of the BangBox chamber pressure are shown in Table 5.1.

5.2 EMISSION FACTORS

Except for the 42-component list of VOCs, emission factors are presented only for target analytes that were detected. Ozone (O_3) was consumed during every trial and, therefore, is not presented with the other target inorganic gases.

5.2.1 Detonating Cord

5.2.1.1 Target Inorganic Gases. The emission factors for target inorganic gases (measured with real-time analyzers or sampled with SUMMA® canisters and assayed using GC/FID) from the detonation of the detonating cord are presented in Table 5.2.

5.2.1.2 Volatile Organic Compounds (VOCs)

a. The emission factors for total NMOCs and groups of VOCs (sampled with SUMMA® canisters and assayed using GC/FID) from the detonation of the detonating cord are presented in Table 5.3. The complete target list of VOCs is given in Section 3.2.

b. The emission factors for the 42-component list of VOCs (sampled with SUMMA® canisters and assayed using GC/MS) from the detonation of the detonating cord are presented in Table 5.4.

5.2.1.3 Semivolatile Organic Compounds (SVOCs)

a. The emission factors for SVOCs (sampled with high-volume and PM_{10} samplers and assayed using GC/MS) from the detonation of the detonating cord are presented in Table 5.5. The complete target list of SVOCs is given in Paragraph 3.2.

b. The emission factors for SVOCs (sampled with PS-1 samplers and assayed using GC/MS) from the detonation of the detonating cord are presented in Table 5.6.

5.2.1.4 Metals. The emission factors for metals (sampled with high-volume and PM_{10} samplers and assayed using ICP/OES and CVAA spectrometry) from the detonation of the detonating cord are presented in Table 5.7.

5.2.1.5 Particulate Matter Less Than Ten Microns in Diameter (PM_{10}). The emission factors for PM_{10} from the detonation of detonating cord for trials 1, 2, and 3 are 3.05e-02 g/g, 2.73e-02 g/g, and 2.71e-02 g/g, respectively. The average is 2.83e-02 g/g with a standard deviation of 1.91e-03 g/g.

5.2.2 Tritonal Surrogate

5.2.2.1 Target Inorganic Gases. The emission factors for target inorganic gases (measured with real-time analyzers or sampled with SUMMA® canisters and assayed using GC/FID) from the detonation of tritonal surrogate are presented in Table 5.8.

Table 5.1. Calculated BangBox Chamber Volumes and Exponential Rates of Change (k_1) from Chamber Pressure Maintenance Dilution Model.

Material	Trial Number	Trial Date (1995)	Volume (m^3)	Rate of Change (min^{-1})	Correlation Coefficient (r^2)
Detonating cord	1	8/15	807.5	-0.0095	0.9907
	2	8/15	782.5	-0.0092	0.9993
	3	8/15	798.9	-0.0093	0.9992
Tritonal surrogate	1	8/16	800.8	-0.0093	0.9994
	2	8/16	799.9	-0.0089	0.9999
	3	8/16	800.4	-0.0099	0.9972
Tritonal surrogate with calcium stearate	1	8/17	823.6	-0.0092	0.9992
	2	8/17	956.0[a]	-0.0084	0.9996
	3	8/17	809.5	-0.0087	0.9958
Amatol surrogate	1	8/18	829.7	-0.0091	0.9969
	2	8/18	823.6	-0.0096	0.9995
	3	8/18	824.9	-0.0089	0.9991
Composition B surrogate	1	8/19	822.0	-0.0097	0.9955
	2	8/19	820.7	-0.0092	0.9998
	3	8/19	807.2	-0.0092	0.9985
HBX surrogate	1	8/21	809.6	-0.0091	0.9996
	2	8/21	904.2	-0.0098	0.9990
	3	8/21	820.2	-0.0095	0.9989
Tritonal surrogate with water	1	8/22	820.0	-0.0111	0.9988
	2	8/22	807.8	-0.0103	0.9988
	3	8/22	821.0	-0.0108	0.9978
Manufacturer's waste	1	8/23	815.3	-0.0092	0.9928
	2	8/24	833.2	-0.0074	0.9958
	3	8/25	833.5	-0.0078	0.9958
Amatol surrogate with water	1	8/28	817.8	-0.0100	0.9995
	2	8/28	805.0	-0.1060	0.9663
	3	8/28	NA[b]	NA	NA
Diesel fuel and dunnage	1	8/29	810.0	-0.0100	0.9994
	2	8/30	819.0	-0.0112	0.9927
	3	8/30	846.0	-0.0102	0.9980
Average			818.3	-0.0095	0.9968
Standard Deviation			21.3	0.0009	0.0063

[a]SF_6 canister suspected of leaking before release; therefore, this value was not included in the average.
[b]Not applicable (canister failed to release).

Table 5.2. Emission Factors for Target Inorganic Gases from the Detonation of the Detonating Cord.

Analyte	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)
Real-Time Analyzer					
CO_2	3.06e+00	2.95e+00	3.05e+00	3.02e+00	6.08e-02
CO	2.35e-02	2.99e-02	2.61e-02	2.65e-02	3.22e-03
NO	3.21e-03	3.41e-03	3.49e-03	3.37e-03	1.44e-04
NO_2	1.26e-04	1.94e-04	2.58e-04	1.93e-04	6.60e-05
SO_2	2.22e-03	2.39e-03	2.34e-03	2.32e-03	8.74e-05
SUMMA® Canister					
CO_2	2.88e+00	2.68e+00	2.89e+00	2.82e+00	1.18e-01
CO	2.11e-02	3.02e-02	2.56e-02	2.56e-02	4.55e-03

Table 5.3. Emission Factors for Total Nonmethane Organic Compounds (NMOCs) and Groups of Volatile Organic Compounds (VOCs) from the Detonation of Detonating Cord.

Analyte	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)
Alkanes (Paraffins)	2.83e-04	3.35e-04	5.08e-04	3.75e-04	1.18e-04
Alkenes (Olefins)	2.63e-03	3.17e-03	2.90e-03	2.90e-03	2.68e-04
Aromatics	2.12e-04	2.32e-04	2.49e-04	2.31e-04	1.89e-05
TUHCs[a]	6.78e-04	9.42e-04	7.76e-04	7.99e-04	1.33e-04
TNMHCs[b]	3.80e-03	4.68e-03	4.43e-03	4.30e-03	4.51e-04
Total NMOCs	4.34e-03	5.68e-03	5.84e-03	5.29e-03	8.24e-04

[a]Total unidentified hydrocarbons.
[b]Total nonmethane hydrocarbons.

5.2.2.2 Volatile Organic Compounds (VOCs)

a. The emission factors for total NMOCs and groups of VOCs (sampled with SUMMA® canisters and assayed using GC/FID) from the detonation of tritonal surrogate are presented in Table 5.9. The complete target list of VOCs is given in Paragraph 3.2.

b. The emission factors for the 42-component list of VOCs (sampled with SUMMA® canisters and assayed using GC/MS) from the detonation of tritonal surrogate are presented in Table 5.10.

Table 5.4. Emission Factors for 42-Component List of Volatile Organic Compounds (VOCs) from the Detonation of the Detonating Cord.

Analyte	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)
Allyl chloride	BDL[a]	BDL	BDL	ND[b]	ND
Benzene	7.48e-05	9.27e-05	9.63e-05	8.79e-05	1.15e-05
Benzyl chloride	BDL	BDL	BDL	ND	ND
1,3-Butadiene	5.46e-05	7.56e-05	9.96e-05	7.66e-05	2.25e-05
Carbon tetrachloride	-[c]	BDL	BDL	-	ND
Chlorobenzene	BDL	BDL	BDL	ND	ND
Chloroform	BDL	BDL	BDL	ND	ND
1,2-Dibromoethane	BDL	BDL	BDL	ND	ND
m-Dichlorobenzene	BDL	BDL	BDL	ND	ND
o-Dichlorobenzene	BDL	BDL	BDL	ND	ND
p-Dichlorobenzene	BDL	BDL	BDL	ND	ND
1,1-Dichloroethane	BDL	BDL	BDL	ND	ND
1,2-Dichloroethane	BDL	BDL	BDL	ND	ND
cis-1,2-Dichloroethylene	BDL	BDL	BDL	ND	ND
Dichloromethane	4.20e-07	2.03e-06	1.66e-06	1.37e-06	8.44e-07
1,2-Dichloropropane	BDL	BDL	BDL	ND	ND
cis-1,3-Dichloropropene	BDL	BDL	BDL	ND	ND
trans-1,3-Dichloropropene	BDL	BDL	BDL	ND	ND
Ethylbenzene	5.46e-06	6.10e-06	7.06e-06	6.20e-06	8.04e-07
Ethyl chloride	BDL	BDL	BDL	ND	ND
p-Ethyltoluene	1.26e-06	1.22e-06	8.30e-07	1.10e-06	2.37e-07
Freon® 11	4.20e-07	1.22e-06	8.30e-07	8.23e-07	4.00e-07
Freon® 12	5.04e-06	4.47e-06	4.15e-06	4.55e-06	4.51e-07
Freon® 114	-	-	-	-	ND
Freon® 113	-	-	-	-	ND
Hexachlorobutadiene	BDL	BDL	BDL	ND	ND
Methyl bromide	BDL	BDL	BDL	ND	ND
Methyl chloride	2.10e-06	2.44e-06	2.49e-06	2.34e-06	2.12e-07
Methyl chloroform	4.20e-07	4.06e-07	4.15e-07	4.14e-07	6.94e-09
Styrene	2.52e-06	2.44e-06	2.08e-06	2.34e-06	2.37e-07
1,1,2,2-Tetrachloroethane	BDL	BDL	BDL	ND	ND
Tetrachloroethylene	6.72e-06	7.31e-06	6.64e-06	6.89e-06	3.68e-07
Toluene	2.27e-05	2.80e-05	3.07e-05	2.71e-05	4.09e-06
1,2,4-Trichlorobenzene	BDL	BDL	BDL	ND	ND
1,1,2-Trichloroethane	BDL	BDL	BDL	ND	ND
Trichloroethylene	BDL	BDL	BDL	ND	ND
1,2,4-Trimethylbenzene	1.68e-06	8.13e-07	4.15e-07	9.69e-07	6.47e-07
1,3,5-Trimethylbenzene	4.20e-07	-	-	< 4.20e-07	ND
m-, p-Xylene	1.43e-05	1.54e-05	1.70e-05	1.56e-05	1.37e-06
o-Xylene	5.88e-06	6.10e-06	6.64e-06	6.21e-06	3.92e-07
Vinyl chloride	BDL	BDL	BDL	ND	ND
Vinylidene chloride	BDL	BDL	BDL	ND	ND

[a]Below detection limit.

[b]Not determinable.

[c]Sample concentration became a negative value when corrected for background concentration.

Table 5.5. Emission Factors for Semivolatile Organic Compounds (SVOCs) (Sampled with High-Volume and PM_{10}[a] Samplers) from the Detonation of the Detonating Cord.

Analyte	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)	PM_{10} Sampler Average[b] (g/g)
a,a-Dimethylphenethylamine	BDL[c]	BDL	BDL	ND[d]	ND	3.11e-07
bis(2-Ethylhexyl) phthalate	7.02e-06	3.77e-06	3.71e-06	4.83e-06	1.89e-06	9.39e-06
Butylbenzyl phthalate	1.12e-06	9.46e-07	1.11e-06	1.06e-06	9.60e-08	1.66e-06
Di-n-butyl phthalate	7.69e-08	-[e]	1.43e-07	< 1.10e-07	ND	1.37e-06
Di-n-octyl phthalate	5.48e-06	5.18e-06	6.13e-06	5.60e-06	4.86e-07	1.16e-05
Diethyl phthalate	-	-	-	-	ND	9.39e-07
N-Nitrosodiethylamine	1.89e-07	BDL	BDL	< 1.89e-07	ND	BDL

[a]Particulate matter less than ten microns in diameter.
[b]Average of trials 1, 2, and 3.
[c]Below detection limit.
[d]Not determinable.
[e]Sample concentration became a negative value when corrected for background concentration.

Table 5.6. Emission Factors for Semivolatile Organic Compounds (SVOCs) (Sampled with PS[a]-1 Samplers) from the Detonation of the Detonating Cord.

Analyte	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)
2-Methylnaphthalene	3.19e-07	2.61e-07	9.16e-07	4.99e-07	3.63e-07
Acetophenone	1.13e-05	1.28e-05	1.64e-05	1.35e-05	2.65e-06
Benzyl alcohol	2.18e-05	2.69e-05	3.61e-05	2.83e-05	7.24e-06
bis(2-Ethylhexyl) phthalate	5.55e-06	5.74e-06	2.29e-06	4.52e-06	1.94e-06
Butylbenzyl phthalate	BDL[b]	BDL	1.95e-06	< 1.95e-06	ND[c]
Di-n-butyl phthalate	-[d]	2.15e-06	2.50e-06	< 2.33e-06	ND
Diethyl phthalate	-	9.48e-07	7.46e-06	< 4.20e-06	ND
Naphthalene	3.83e-06	4.08e-06	4.69e-06	4.20e-06	4.45e-07
Phenol	1.68e-05	2.04e-05	2.32e-05	2.01e-05	3.22e-06

[a]Pesticide sampler.
[b]Below detection level.
[c]Not determinable.
[d]Sample concentration became a negative value when corrected for background concentration.

Table 5.7. Emission Factors for Metals from the Detonation of the Detonating Cord.

Analyte	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)	PM_{10}[a] Sampler Average[b] (g/g)
Aluminum	8.19e-04	5.65e-04	3.88e-04	5.91e-04	2.17e-04	1.44e-03
Antimony	BDL[c]	BDL	BDL	ND[d]	ND	BDL
Arsenic	BDL	BDL	BDL	ND	ND	BDL
Barium	1.00e-05	6.19e-06	4.70e-06	6.97e-06	2.76e-06	8.67e-06
Cadmium	2.03e-06	1.27e-06	8.64e-07	1.39e-06	5.93e-07	1.37e-06
Calcium	2.73e-03	1.94e-03	1.50e-03	2.06e-03	6.24e-04	2.09e-03
Chromium	5.69e-06	4.19e-06	3.21e-06	4.36e-06	1.25e-06	5.06e-06
Copper	1.74e-04	1.03e-04	7.16e-05	1.16e-04	5.23e-05	1.95e-04
Lead	7.32e-04	7.62e-04	6.42e-04	7.12e-04	6.26e-05	8.67e-04
Mercury	2.09e-09	7.39e-07	6.54e-05	2.21e-05	3.76e-05	3.32e-08
Nickel	4.20e-06	3.43e-06	1.73e-06	3.12e-06	1.26e-06	2.67e-06
Potassium	2.30e-04	1.78e-04	1.36e-04	1.81e-04	4.74e-05	1.95e-04
Sodium	1.34e-03	1.27e-03	1.10e-03	1.23e-03	1.25e-04	1.81e-03
Titanium	1.96e-05	1.71e-05	1.41e-05	1.69e-05	2.73e-06	1.88e-05
Zinc	5.76e-04	6.17e-04	4.75e-04	5.56e-04	7.27e-05	6.28e-04

[a]Particulate matter less than ten microns in diameter.
[b]Average of trials 1, 2, and 3.
[c]Below detection limit.
[d]Not determinable.

Table 5.8. Emission Factors for Target Inorganic Gases from the Detonation of Tritonal Surrogate.

Analyte	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)
Real-Time Analyzer					
CO_2	5.90e-01	2.39e-01	1.27e+00	7.00e-01	5.24e-01
CO	4.78e-03	4.81e-03	2.34e-03	3.98e-03	1.42e-03
NO	1.32e-03	1.74e-02	5.85e-03	8.19e-03	8.29e-03
NO_2	2.52e-04	1.93e-04	1.84e-05	1.54e-04	1.21e-04
SO_2	1.16e-04	2.80e-04	7.80e-05	1.58e-04	1.07e-04
SUMMA® Canister					
CO_2	4.96e-01	2.17e-01	1.21e+00	6.41e-01	5.12e-01
CO	5.55e-03	5.60e-03	2.88e-03	4.68e-03	1.56e-03

Table 5.9. Emission Factors for Total Nonmethane Organic Compounds (NMOCs) and Groups of Volatile Organic Compounds (VOCs) from the Detonation of Tritonal Surrogate.

Analyte	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)
Alkanes (Paraffins)	3.72e-06	BDL[a]	1.63e-05	< 1.00e-05	ND[b]
Alkenes (Olefins)	2.36e-04	1.52e-04	8.31e-05	1.57e-04	7.64e-05
Aromatics	3.42e-05	2.23e-05	2.32e-05	2.66e-05	6.66e-06
TUHCs[c]	1.20e-04	9.57e-05	5.37e-05	8.97e-05	3.35e-05
TNMHCs[d]	3.93e-04	2.59e-04	1.76e-04	2.76e-04	1.10e-04
Total NMOCs	2.98e-04	2.93e-04	2.00e-04	2.63e-04	5.53e-05

[a]Below detection limit.
[b]Not determinable.
[c]Total unidentified hydrocarbons.
[d]Total nonmethane hydrocarbons.

Table 5.10. Emission Factors for 42-Component List of Volatile Organic Compounds (VOCs) from the Detonation of Tritonal Surrogate.

Analyte	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)
Allyl chloride	BDL[a]	BDL	BDL	ND[b]	ND
Benzene	1.08e-05	4.82e-06	2.90e-06	6.17e-06	4.11e-06
Benzyl chloride	BDL	BDL	BDL	ND	ND
1,3-Butadiene	BDL	BDL	BDL	ND	ND
Carbon tetrachloride	-[c]	3.71e-07	-	< 3.71e-07	ND
Chlorobenzene	BDL	BDL	BDL	ND	ND
Chloroform	-	-	3.63e-07	< 3.63e-07	ND
1,2-Dibromoethane	BDL	BDL	BDL	ND	ND
m-Dichlorobenzene	BDL	BDL	BDL	ND	ND
o-Dichlorobenzene	BDL	BDL	BDL	ND	ND
p-Dichlorobenzene	BDL	BDL	BDL	ND	ND
1,1-Dichloroethane	BDL	BDL	BDL	ND	ND
1,2-Dichloroethane	BDL	BDL	BDL	ND	ND
cis-1,2-Dichloroethylene	BDL	BDL	BDL	ND	ND
Dichloromethane	3.35e-06	4.75e-05	2.54e-06	1.78e-05	2.57e-05
1,2-Dichloropropane	BDL	BDL	BDL	ND	ND
cis-1,3-Dichloropropene	BDL	BDL	BDL	ND	ND
trans-1,3-Dichloropropene	BDL	BDL	BDL	ND	ND
Ethylbenzene	1.12e-06	2.60e-06	3.27e-06	2.33e-06	1.10e-06
Ethyl chloride	BDL	BDL	BDL	ND	ND
p-Ethyltoluene	-	-	3.63e-07	< 3.63e-07	ND
Freon® 11	3.72e-07	7.42e-07	7.26e-07	6.13e-07	2.09e-07
Freon® 12	2.23e-06	3.71e-07	-	< 1.30e-06	ND
Freon® 114	-	-	-	-	ND
Freon® 113	-	-	-	-	ND
Hexachlorobutadiene	BDL	BDL	BDL	ND	ND
Methyl bromide	BDL	BDL	BDL	ND	ND
Methyl chloride	7.44e-07	3.71e-07	BDL	<5.58e-07	ND
Methyl chloroform	-	-	-	-	ND
Styrene	3.72e-07	-	-	< 3.72e-07	ND
1,1,2,2-Tetrachloroethane	BDL	BDL	BDL	ND	ND
Tetrachloroethylene	1.86e-06	3.34e-06	2.90e-06	2.70e-06	7.59e-07
Toluene	3.35e-06	1.48e-06	3.99e-06	2.94e-06	1.30e-06
1,2,4-Trichlorobenzene	BDL	BDL	BDL	ND	ND
1,1,2-Trichloroethane	BDL	BDL	BDL	ND	ND
Trichloroethylene	BDL	BDL	BDL	ND	ND
1,2,4-Trimethylbenzene	-	3.71e-07	-	< 3.71e-07	ND
1,3,5-Trimethylbenzene	-	-	-	-	ND
m-, p-Xylene	5.21e-06	8.16e-06	9.80e-06	7.72e-06	2.32e-06
o-Xylene	2.23e-06	2.97e-06	3.99e-06	3.06e-06	8.83e-07
Vinyl chloride	BDL	BDL	BDL	ND	ND
Vinylidene chloride	BDL	BDL	BDL	ND	ND

[a]Below detection limit.

[b]Not determinable.

[c]Sample concentration became a negative value when corrected for background concentration.

5.2.2.3 Semivolatile Organic Compounds (SVOCs)

a. The emission factors for SVOCs (sampled with high-volume and PM_{10} samplers and assayed using GC/MS) from the detonation of tritonal surrogate are presented in Table 5.11. The complete target list of SVOCs is given in Paragraph 3.2.

b. The emission factors for SVOCs (sampled with PS-1 samplers and assayed using GC/MS) from the detonation of tritonal surrogate are shown in Table 5.12.

5.2.2.4 Metals. The emission factors for metals (sampled with high-volume and PM_{10} samplers and assayed using ICP/OES and CVAA spectrometry) from the detonation of tritonal surrogate are shown in Table 5.13.

5.2.2.5 Particulate Matter Less Than Ten Microns in Diameter (PM_{10}). The emission factors for PM_{10} from the detonation of tritonal surrogate for trials 1, 2, and 3 are 6.31e-01 g/g, 2.54e-01 g/g, and 2.22e-01 g/g, respectively. The average is 3.69e-01 g/g with a standard deviation of 2.27e-01 g/g.

5.2.3 Tritonal Surrogate with Calcium Stearate

Incomplete detonation occurred during Trial 1; these results are not presented.

5.2.3.1 Target Inorganic Gases. The emission factors for target inorganic gases (measured with real-time analyzers or sampled with SUMMA® canisters and assayed using GC/FID) from the detonation of tritonal surrogate with calcium stearate are presented in Table 5.14.

5.2.3.2 Volatile Organic Compounds (SVOCs)

a. The emission factors for total NMOCs groups of VOCs (sampled with SUMMA® canisters and assayed using GC/FID) from the detonation of tritonal surrogate with calcium stearate are presented in Table 5.15. The complete target list of VOCs is given in Paragraph 3.2.

b. The emission factors for the 42-component list of VOCs (sampled with SUMMA® canisters and assayed using GC/MS) from the detonation of tritonal surrogate with calcium stearate are presented in Table 5.16.

5.2.3.3 Semivolatile Organic Compounds (SVOCs)

a. The emission factors for SVOCs (sampled with high-volume and PM_{10} samplers and assayed using GC/MS) from the detonation of tritonal surrogate with calcium stearate are presented in Table 5.17. The complete target list of SVOCs is given in Paragraph 3.2.

b. The emission factors for SVOCs (sampled with PS-1 samplers and assayed using GC/MS) from the detonation of tritonal surrogate with calcium stearate are presented in Table 5.18.

5.2.3.4 Metals. The emission factors for metals (sampled with high-volume and PM_{10} samplers and assayed using ICP/OES and CVAA spectrometry) from the detonation of tritonal surrogate with calcium stearate are presented in Table 5.19.

5.2.3.5 Particulate Matter Less Than Ten Microns in Diameter (PM_{10}). The emission factors for PM_{10} from the detonation of tritonal surrogate with calcium stearate for trials 2 and 3 are 2.29e-01 g/g and 2.98e-01 g/g, respectively. The average is 2.64e-01 g/g with a standard deviation of 4.88e-02 g/g.

Table 5.11. Emission Factors for Semivolatile Organic Compounds (SVOCs) (Sampled with High-Volume and PM_{10}[a] Samplers) from the Detonation of Tritonal Surrogate.

Analyte	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)	PM_{10} Sampler Trial 3 (g/g)
1,3-Dinitrobenzene	3.21e-06	BDL[b]	3.16e-07	< 1.77e-06	ND[c]	BDL
2,4-Dinitrotoluene	2.46e-05	1.92e-06	3.33e-06	9.94e-06	1.27e-05	7.16e-07
4,6-Dinitro-2-methylphenone	BDL	BDL	2.33e-07	< 2.33e-07	ND	BDL
4-Nitrophenol	2.27e-05	1.65e-05	1.83e-06	1.37e-05	1.07e-05	4.13e-04
Anthracene	BDL	6.16e-06	BDL	< 6.16e-06	ND	BDL
Benzyl alcohol	1.42e-06	4.23e-07	2.83e-07	7.08e-07	6.19e-07	BDL
bis(2-Ethylhexyl) phthalate	-[d]	-	-	-	ND	BDL
Butylbenzyl phthalate	2.80e-06	7.33e-07	2.17e-06	1.90e-06	1.06e-06	5.78e-07
Di-n-butyl phthalate	3.68e-08	2.18e-04	5.57e-07	7.28e-05	1.26e-04	BDL
Di-n-octyl phthalate	1.09e-05	4.35e-06	8.17e-06	7.79e-06	3.27e-06	1.90e-06
Diethyl phthalate	-	1.13e-07	1.04e-07	< 1.09e-07	ND	3.03e-07
Dimethyl phthalate	BDL	-	8.51e-08	< 8.51e-08	ND	BDL

[a]Particulate matter less than ten microns in diameter.
[b]Below detection limit.
[c]Not determinable.
[d]Sample concentration became a negative value when corrected for background concentration.

Table 5.12. Emission Factors for Semivolatile Organic Compounds (SVOCs) (Sampled with PS[a]-1 Samplers) from the Detonation of Tritonal Surrogate.

Analyte	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)
2,4-Dinitrotoluene	1.05e-04	8.17e-05	1.61e-05	6.76e-05	4.60e-05
2-Methylnapthalene	-[b]	3.45e-06	5.05e-07	< 1.98e-06	ND[c]
4-Nitrophenol	BDL[d]	3.19e-05	BDL	< 3.19e-05	ND
Acetophenone	-	2.59e-05	3.25e-06	< 1.46e-05	ND
Benzyl alcohol	-	7.14e-05	4.03e-05	< 5.59e-05	ND
bis(2-Ethylhexyl) phthalate	-	7.39e-06	-	< 7.39e-06	ND
Di-n-butyl phthalate	3.71e-05	6.26e-05	1.51e-05	3.83e-05	2.38e-05
Diethyl phthalate	-	1.72e-05	6.83e-06	< 1.20e-05	ND
Naphthalene	1.98e-05	1.91e-05	3.22e-06	1.41e-05	9.39e-06
Phenol	-	2.68e-05	5.65e-06	< 1.63e-05	ND

[a]Pesticide sampler.
[b]Sample concentration became a negative value when corrected for background concentration.
[c]Not determinable.
[d]Below detection level.

Table 5.13. Emission Factors for Metals from the Detonation of Tritonal Surrogate.

Analyte	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)	PM_{10}[a] Sampler Trial 3 (g/g)
Aluminum	4.24e-02	1.84e-02	1.69e-02	2.59e-02	1.43e-02	7.43e-03
Antimony	BDL[b]	BDL	BDL	ND[c]	ND	BDL
Arsenic	BDL	BDL	BDL	ND	ND	BDL
Barium	8.39e-04	2.25e-04	5.27e-04	5.30e-04	3.07e-04	3.58e-04
Cadmium	BDL	BDL	1.86e-06	< 1.86e-06	ND	BDL
Calcium	2.34e-03	4.08e-04	3.40e-03	2.05e-03	1.52e-03	2.15e-03
Chromium	1.13e-05	4.93e-06	4.31e-06	6.84e-06	3.85e-06	3.58e-06
Copper	9.14e-05	-[d]	1.81e-04	< 1.36e-04	ND	1.43e-04
Lead	2.49e-03	1.31e-03	1.26e-03	1.69e-03	6.96e-04	1.02e-03
Mercury	-	-	-	-	ND	2.75e-08
Nickel	BDL	BDL	4.31e-06	< 4.31e-06	ND	BDL
Potassium	2.34e-04	1.08e-04	2.12e-04	1.85e-04	6.75e-05	1.10e-04
Sodium	7.60e-04	3.83e-04	2.97e-04	4.80e-04	2.46e-04	8.81e-04
Titanium	2.19e-05	4.52e-06	1.81e-05	1.49e-05	9.16e-06	1.02e-05
Zinc	3.22e-04	7.47e-05	2.25e-04	2.07e-04	1.25e-04	1.16e-04

[a]Particulate matter less than ten microns in diameter.
[b]Below detection limit.
[c]Not determinable.
[d]Sample concentration became a negative value when corrected for background concentration.

Table 5.14. Emission Factors for Target Inorganic Gases from the Detonation of Tritonal Surrogate with Calcium Stearate.

Analyte	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)
Real-Time Analyzer				
CO_2	1.42e+00	1.42e+00	1.42e+00	0.00e+00
CO	3.99e-03	1.57e-03	2.78e-03	1.71e-03
NO	6.53e-03	6.65e-03	6.59e-03	8.49e-05
NO_2	3.03e-05	5.93e-05	4.48e-05	2.05e-05
SO_2	1.76e-04	6.70e-05	1.22e-04	7.71e-05
SUMMA® Canister				
CO_2	1.30e+00	1.29e+00	1.30e+00	7.07e-03
CO	3.27e-03	2.02e-03	2.65e-03	8.84e-04

Table 5.15. Emission Factors for Total Nonmethane Organic Compounds (NMOCs) and Groups of Volatile Organic Compounds (VOCs) from the Detonation of Tritonal Surrogate with Calcium Stearate.

Analyte	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)
Alkanes (Paraffins)	-[a]	-	-	ND[b]
Alkenes (Olefins)	7.58e-05	4.70e-05	6.14e-05	2.03e-05
Aromatics	-	1.42e-05	< 1.42e-05	1.01e-05
TUHCs[c]	-	3.64e-06	< 3.64e-06	2.58e-06
TNMHCs[d]	2.80e-05	5.14e-05	3.97e-05	1.66e-05
Total NMOCs	2.43e-04	1.97e-04	2.20e-04	3.25e-05

[a]Sample concentration became a negative value when corrected for background concentration.
[b]Not determinable.
[c]Total unidentified hydrocarbons.
[d]Total nonmethane hydrocarbons.

Table 5.16. Emission Factors for 42-Component List of Volatile Organic Compounds (VOCs) from the Detonation of Tritonal Surrogate with Calcium Stearate.

Analyte	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)
Allyl chloride	BDL[a]	BDL	ND[b]	ND
Benzene	5.52e-06	3.64e-06	4.58e-06	1.32e-06
Benzyl chloride	BDL	BDL	ND	ND
1,3-Butadiene	BDL	BDL	ND	ND
Carbon tetrachloride	-[c]	-	-	ND
Chlorobenzene	1.10e-06	3.64e-07	7.34e-07	5.22e-07
Chloroform	-	-	-	ND
1,2-Dibromoethane	BDL	BDL	ND	ND
m-Dichlorobenzene	BDL	BDL	ND	ND
o-Dichlorobenzene	BDL	BDL	ND	ND
p-Dichlorobenzene	BDL	BDL	ND	ND
1,1-Dichloroethane	BDL	BDL	ND	ND
1,2-Dichloroethane	-	-	-	ND
cis-1,2-Dichloroethylene	BDL	BDL	ND	ND
Dichloromethane	6.25e-06	3.11e-04	1.59e-04	2.16e-04
1,2-Dichloropropane	BDL	BDL	ND	ND
cis-1,3-Dichloropropene	BDL	BDL	ND	ND
trans-1,3-Dichloropropene	BDL	BDL	ND	ND
Ethylbenzene	2.94e-06	2.19e-06	2.56e-06	5.34e-07
Ethyl chloride	BDL	BDL	ND	ND
p-Ethyltoluene	3.68e-07	-	< 3.68e-07	ND
Freon® 11	7.36e-07	3.64e-07	5.50e-07	2.62e-07
Freon® 12	-	7.29e-07	< 7.29e-07	ND
Freon® 114	3.68e-07	3.64e-07	3.66e-07	2.35e-09
Freon® 113	-	-	-	ND
Hexachlorobutadiene	BDL	BDL	ND	ND
Methyl bromide	BDL	BDL	ND	ND
Methyl chloride	3.68e-07	3.64e-07	3.66e-07	2.35e-09
Methyl chloroform	BDL	BDL	ND	ND
Styrene	BDL	BDL	ND	ND
1,1,2,2-Tetrachloroethane	BDL	BDL	ND	ND
Tetrachloroethylene	3.68e-07	3.64e-07	3.66e-07	2.35e-09
Toluene	3.31e-06	3.64e-07	1.84e-06	2.08e-06
1,2,4-Trichlorobenzene	BDL	BDL	ND	ND
1,1,2-Trichloroethane	BDL	BDL	ND	ND
Trichloroethylene	BDL	BDL	ND	ND
1,2,4-Trimethylbenzene	-	-	-	ND
1,3,5-Trimethylbenzene	-	-	-	ND
m-, p-Xylene	7.36e-06	6.56e-06	6.96e-06	5.62e-07
o-Xylene	3.68e-06	2.55e-06	3.11e-06	7.97e-07
Vinyl chloride	BDL	BDL	ND	ND
Vinylidene chloride	BDL	BDL	ND	ND

[a]Below detection limit.

[b]Not determinable.

[c]Sample concentration became a negative value when corrected for background concentration.

Table 5.17. Emission Factors for Semivolatile Organic Compounds (SVOCs) (Sampled with High-Volume and PM_{10}[a] Samplers) from the Detonation of Tritonal Surrogate with Calcium Stearate.

Analyte	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)	PM_{10} Sampler Average[b] (g/g)
1,3,5-Trinitrobenzene	3.74e-06	BDL[c]	< 3.74e-06	ND[d]	BDL
2,4-Dinitrotoluene	5.82e-07	1.06e-06	8.21e-07	2.40e-07	1.11e-06
4-Nitrophenol	3.95e-07	BDL	< 3.95e-07	ND	BDL
Acetophenone	-[e]	-	-	ND	BDL
Benzyl alcohol	2.49e-07	BDL	< 2.49e-07	ND	BDL
bis(2-Ethylhexyl) phthalate	4.36e-06	5.30e-06	4.83e-06	4.71e-07	8.08e-06
Butylbenzyl phthalate	1.43e-06	1.44e-06	1.43e-06	5.18e-09	2.54e-06
Di-n-octyl phthalate	4.17e-06	4.90e-06	4.54e-06	3.66e-07	1.08e-05
Diethyl phthalate	1.24e-07	6.55e-08	9.48e-08	2.94e-08	1.02e-06
Dimethyl phthalate	1.76e-07	-	< 1.76e-07	ND	BDL
Fluoranthene	BDL	5.25e-07	< 5.25e-07	ND	BDL

[a]Particulate matter less than ten microns in diameter.
[b]Average of trials 2 and 3.
[c]Below detection limit.
[d]Not determinable.
[e]Sample concentration became a negative value when corrected for background.

Table 5.18. Emission Factors for Semivolatile Organic Compounds (SVOCs) (Sampled with PS[a]-1 Samplers) from the Detonation of Tritonal Surrogate with Calcium Stearate.

Analyte	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)
Acetophenone	9.45e-07	-[b]	< 9.45e-07	ND[c]
Benzyl alcohol	5.92e-06	-	< 5.92e-06	ND
bis(2-Ethylhexyl) phthalate	-	-	-	ND
Di-n-butyl phthalate	-	-	-	ND
Diethyl phthalate	6.34e-06	-	< 6.34e-06	ND
Naphthalene	1.99e-06	-	< 1.99e-06	ND
Phenol	1.86e-06	-	< 1.86e-06	ND

[a]Pesticide sampler.
[b]Sample concentration became a negative value when corrected for background concentration.
[c]Not determinable.

Table 5.19. Emission Factors for Metals from the Detonation of Tritonal Surrogate with Calcium Stearate.

Analyte	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)	PM_{10}[a] Sampler Average[b] (g/g)
Aluminum	1.71e-02	1.77e-02	1.74e-02	4.69e-04	1.35e-02
Antimony	BDL[c]	BDL	ND[d]	ND	BDL
Arsenic	BDL	BDL	ND	ND	BDL
Barium	6.82e-04	7.78e-04	7.30e-04	6.79e-05	6.88e-04
Cadmium	6.00e-06	4.78e-06	5.39e-06	8.65e-07	6.58e-06
Calcium	6.64e-03	6.73e-03	6.68e-03	6.65e-05	5.68e-03
Chromium	8.14e-06	8.72e-06	8.43e-06	4.07e-07	1.11e-05
Copper	5.84e-04	4.63e-04	5.24e-04	8.56e-05	5.09e-04
Lead	1.50e-03	1.52e-03	1.51e-03	1.41e-05	1.85e-03
Mercury	4.88e-08	5.04e-08	4.96e-08	1.12e-09	8.38e-08
Nickel	4.28e-06	4.83e-06	4.55e-06	3.94e-07	1.05e-05
Potassium	2.91e-04	2.74e-04	2.82e-04	1.22e-05	2.99e-04
Sodium	5.18e-04	5.39e-04	5.28e-04	1.48e-05	1.23e-03
Titanium	3.13e-05	3.44e-05	3.29e-05	2.16e-06	2.90e-05
Zinc	5.44e-04	3.56e-04	4.50e-04	1.33e-04	3.89e-04

[a]Particulate matter less than ten microns in diameter.
[b]Average of trials 2 and 3.
[c]Below detection limit.
[d]Not determinable.

5.2.4 Amatol Surrogate

5.2.4.1 Target Inorganic Gases. The emission factors for target inorganic gases (measured with real-time analyzers or sampled with SUMMA® canisters and assayed using GC/FID) from the detonation of amatol surrogate are presented in Table 5.20.

5.2.4.2 Volatile Organic Compounds (SVOCs)

a. The emission factors for total NMOCs and groups of VOCs (sampled with SUMMA® canisters and assayed using GC/FID) from the detonation of amatol surrogate are presented in Table 5.21. The complete target list of VOCs is given in Paragraph 3.2.

b. The emission factors for the 42-component list of VOCs (sampled with SUMMA® canisters and assayed using GC/MS) from the detonation of amatol surrogate are presented in Table 5.22.

Table 5.20. Emission Factors for Target Inorganic Gases from the Detonation of Amatol Surrogate.

Analyte	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)
Real-Time Analyzer					
CO_2	6.01e-01	9.15e-01	8.93e-01	8.03e-01	1.75e-01
CO	9.23e-03	7.73e-03	1.08e-02	9.25e-03	1.54e-03
NO	2.21e-02	1.43e-02	1.68e-02	1.77e-02	3.98e-03
NO_2	3.36e-04	1.78e-04	4.15e-04	3.10e-04	1.21e-04
SO_2	3.21e-04	2.11e-04	2.48e-04	2.60e-04	5.60e-05
SUMMA® Canister					
CO_2	5.11e-01	7.79e-01	8.01e-01	6.97e-01	1.61e-01
CO	9.83e-03	8.60e-03	1.07e-02	9.71e-03	1.06e-03

Table 5.21. Emission Factors for Total Nonmethane Organic Compounds (NMOCs) and Groups of Volatile Organic Compounds (VOCs) from the Detonation of Amatol Surrogate.

Analyte	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)
Alkanes (Paraffins)	1.01e-05	1.60e-05	2.12e-05	1.58e-05	5.55e-06
Alkenes (Olefins)	2.47e-04	7.23e-05	9.56e-05	1.38e-04	9.49e-05
Aromatics	5.77e-05	2.83e-05	4.20e-05	4.27e-05	1.47e-05
TUHCs[a]	4.36e-04	2.25e-04	1.02e-04	2.54e-04	1.69e-04
TNMHCs[b]	7.51e-04	3.41e-04	2.60e-04	4.51e-04	2.63e-04
Total NMOCs	9.14e-04	4.81e-04	3.35e-04	5.76e-04	3.01e-04

[a]Total unidentified hydrocarbons.

[b]Total nonmethane hydrocarbons.

Table 5.22. Emission Factors for 42-Component List of Volatile Organic Compounds (VOCs) from the Detonation of Amatol Surrogate.

Compound	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)
Allyl chloride	BDL[a]	BDL	BDL	ND[b]	ND
Benzene	3.41e-05	1.08e-05	1.49e-05	1.99e-05	1.24e-05
Benzyl chloride	BDL	BDL	BDL	ND	ND
1,3-Butadiene	BDL	BDL	BDL	ND	ND
Carbon tetrachloride	3.74e-07	-[c]	-	< 3.74e-07	ND
Chlorobenzene	BDL	BDL	BDL	ND	ND
Chloroform	-	-	-	-	ND
1,2-Dibromoethane	BDL	BDL	BDL	ND	ND
m-Dichlorobenzene	BDL	BDL	BDL	ND	ND
o-Dichlorobenzene	BDL	BDL	BDL	ND	ND
p-Dichlorobenzene	BDL	BDL	BDL	ND	ND
1,1-Dichloroethane	BDL	BDL	BDL	ND	ND
1,2-Dichloroethane	BDL	BDL	BDL	ND	ND
cis-1,2-Dichloroethylene	BDL	BDL	BDL	ND	ND
Dichloromethane	1.45e-04	2.01e-04	1.05e-04	1.50e-04	4.80e-05
1,2-Dichloropropane	BDL	BDL	BDL	ND	ND
cis-1,3-Dichloropropene	BDL	BDL	BDL	ND	ND
trans-1,3-Dichloropropene	BDL	BDL	BDL	ND	ND
Ethylbenzene	1.12e-06	1.49e-06	1.12e-06	1.24e-06	2.15e-07
Ethyl chloride	BDL	BDL	BDL	ND	ND
p-Ethyltoluene	3.74e-07	-	-	< 3.74e-07	ND
Freon® 11	3.74e-07	1.12e-06	8.55e-06	3.35e-06	4.52e-06
Freon® 12	-	3.73e-07	4.46e-06	< 2.42e-06	ND
Freon® 114	-	-	3.72e-07	< 3.72e-07	ND
Freon® 113	-	3.73e-07	-	< 3.73e-07	ND
Hexachlorobutadiene	BDL	BDL	BDL	ND	ND
Methyl bromide	BDL	BDL	BDL	ND	ND
Methyl chloride	1.12e-06	7.45e-07	3.72e-07	7.47e-07	3.76e-07
Methyl chloroform	3.74e-07	3.73e-07	-	< 3.74e-07	ND
Styrene	BDL	BDL	BDL	ND	ND
1,1,2,2-Tetrachloroethane	BDL	BDL	BDL	ND	ND
Tetrachloroethylene	3.74e-07	3.73e-07	-	< 3.74e-07	ND
Toluene	9.73e-06	8.20e-06	3.35e-06	7.09e-06	3.33e-06
1,2,4-Trichlorobenzene	BDL	BDL	BDL	ND	ND
1,1,2-Trichloroethane	BDL	BDL	BDL	ND	ND
Trichloroethylene	BDL	BDL	BDL	ND	ND
1,2,4-Trimethylbenzene	3.74e-07	7.45e-07	7.44e-07	6.21e-07	2.14e-07
1,3,5-Trimethylbenzene	-	-	7.44e-07	< 7.44e-07	ND
m-, p-Xylene	2.62e-06	4.47e-06	3.72e-06	3.60e-06	9.31e-07
o-Xylene	1.12e-06	1.86e-06	1.49e-06	1.49e-06	3.70e-07
Vinyl chloride	BDL	BDL	BDL	ND	ND
Vinylidene chloride	BDL	BDL	BDL	ND	ND

[a]Below detection limit.

[b]Not determinable.

[c]Sample concentration became a negative value when corrected for background concentration.

5.2.4.3 Semivolatile Organic Compounds (SVOCs)

a. The emission factors for SVOCs (sampled with high-volume and PM_{10} samplers and assayed using GC/MS) from the detonation of amatol surrogate are presented in Table 5.23. The complete target list of SVOCs is given in Paragraph 3.2.

b. The emission factors for SVOCs (sampled with PS-1 samplers and assayed using GC/MS) from the detonation of amatol surrogate are presented in Table 5.24.

5.2.4.4 Metals. The emission factors for metals (sampled with high-volume and PM_{10} samplers and assayed using ICP/OES and CVAA spectrometry) from the detonation of amatol surrogate are presented in Table 5.25.

5.2.4.5 Particulate Matter Less Than Ten Microns in Diameter (PM_{10}). The emission factors for PM_{10} from the detonation of amatol surrogate for trials 1, 2, and 3 are 1.53e-02 g/g, 2.05e-02 g/g, and 2.00e-02 g/g, respectively. The average is 1.86e-02 g/g with a standard deviation of 2.87e-03 g/g.

5.2.5 Composition B Surrogate

5.2.5.1 Target Inorganic Gases. The emission factors for target inorganic gases (measured with real-time analyzers or sampled with SUMMA® canisters and assayed using GC/FID) from the detonation of composition B surrogate are presented in Table 5.26.

5.2.5.2 Volatile Organic Compounds (VOCs)

a. The emission factors for total NMOCs and groups of VOCs (sampled with SUMMA® canisters and assayed using GC/FID) from the detonation of composition B surrogate are shown in Table 5.27. The complete target list of VOCs is given in Paragraph 3.2.

b. The emission factors for the 42-component list of VOCs (sampled with SUMMA® canisters and assayed using GC/MS) from the detonation of composition B surrogate are presented in Table 5.28.

5.2.5.3 Semivolatile Organic Compounds (SVOCs)

a. The emission factors for SVOCs (sampled with high-volume and PM_{10} samplers and assayed using GC/MS) from the detonation of composition B surrogate are presented in Table 5.29. The complete target list of SVOCs is given in Paragraph 3.2.

b. The emission factors for SVOCs (sampled with PS-1 samplers and assayed using GC/MS) from the detonation of composition B surrogate are presented in Table 5.30.

5.2.5.4 Metals. The emission factors for metals (sampled with high-volume and PM_{10} samplers and assayed using ICP/OES and CVAA spectrometry) from the detonation of composition B surrogate are presented in Table 5.31.

5.2.5.5 Particulate Matter Less Than Ten Microns in Diameter (PM_{10}). The emission factors for PM_{10} from the detonation of composition B surrogate for trials 1, 2, and 3 are 1.04e-02 g/g, 1.13e-02 g/g, and 1.53e-02 g/g, respectively. The average is 1.23e-02 g/g with a standard deviation of 2.61e-03 g/g.

Table 5.23. Emission Factors for Semivolatile Organic Compounds (SVOCs) (Sampled with High-Volume and PM_{10}[a] Samplers) from the Detonation of Amatol Surrogate.

Analyte	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)	PM_{10} Sampler Average[b] (g/g)
2,4-Dinitrotoluene	6.62e-07	2.86e-07	BDL[c]	< 4.74e-07	ND[d]	4.74e-07
4-Nitrophenol	BDL	3.87e-07	BDL	< 3.87e-07	ND	BDL
Benzo(a)anthracene	1.38e-07	BDL	BDL	< 1.38e-07	ND	BDL
Benzo(a)pyrene	6.07e-08	BDL	BDL	< 6.07e-08	ND	BDL
Benzo(b)fluoranthene	1.16e-07	BDL	BDL	< 1.16e-07	ND	BDL
Benzo(k)fluoranthene	1.16e-07	BDL	BDL	< 1.16e-07	ND	BDL
bis(2-Ethylhexyl) phthalate	1.00e-07	2.74e-07	BDL	< 1.87e-07	ND	1.72e-06
Butylbenzyl phthalate	3.53e-07	6.74e-07	BDL	< 5.13e-07	ND	8.30e-07
Chrysene	1.10e-07	BDL	BDL	< 1.10e-07	ND	BDL
Di-n-butyl phthalate	-[e]	1.23e-07	BDL	< 1.23e-07	ND	1.13e-06
Di-n-octyl phthalate	1.21e-06	1.45e-06	BDL	< 1.33e-06	ND	2.31e-06
Diethyl phthalate	-	1.77e-09	BDL	< 1.77e-09	ND	6.52e-07
Fluoranthene	BDL	BDL	BDL	ND	ND	1.78e-07
Perylene	6.07e-08	BDL	BDL	< 6.07e-08	ND	BDL
Phenanthrene	BDL	1.52e-07	BDL	< 1.52e-07	ND	2.07e-07
Pyrene	1.60e-07	1.01e-07	BDL	< 1.30e-07	ND	2.37e-07

[a]Particulate matter less than ten microns in diameter.
[b]Average of trials 1, 2, and 3.
[c]Below detection limit.
[d]Not determinable.
[e]Sample concentration became a negative value when corrected for background concentration.

Table 5.24. Emission Factors for Semivolatile Organic Compounds (SVOCs) (Sampled with PS[a]-1 Samplers) from the Detonation of Amatol Surrogate.

Analyte	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)
2,4-Dinitrotoluene	9.21e-06	BDL[b]	BDL	< 9.21e-06	ND[c]
2-Methylnphthalene	8.08e-07	BDL	BDL	< 8.08e-07	ND
Acetophenone	-[d]	4.48e-07	9.60e-07	< 7.04e-07	ND
Benzyl alcohol	1.11e-06	3.08e-06	6.64e-06	3.61e-06	2.80e-06
bis(2-Ethylhexyl) phthalate	-	9.39e-06	-	< 9.39e-06	ND
Di-n-butyl phthalate	-	9.03e-06	2.21e-06	< 5.62e-06	ND
Diethyl phthalate	-	5.40e-07	2.98e-06	< 1.76e-06	ND
Naphthalene	2.65e-06	-	6.18e-07	< 1.63e-06	ND
Phenol	5.46e-06	2.47e-06	3.43e-06	3.79e-06	1.53e-06

[a]Pesticide sampler.
[b]Below detection level.
[c]Not determinable.
[d]Sample concentration became a negative value when corrected for background concentration.

Table 5.25. Emission Factors for Metals from the Detonation of Amatol Surrogate.

Analyte	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)	PM_{10}[a] Sampler Average[b] (g/g)
Aluminum	2.63e-04	3.76e-04	3.16e-04	3.18e-04	5.61e-05	3.85e-04
Antimony	BDL[c]	BDL	BDL	ND[d]	ND	BDL
Arsenic	BDL	BDL	BDL	ND	ND	BDL
Barium	3.32e-04	3.94e-04	4.02e-04	3.76e-04	3.83e-05	4.21e-04
Cadmium	6.10e-07	2.79e-06	1.69e-06	1.70e-06	1.09e-06	1.84e-06
Calcium	3.62e-04	8.79e-04	1.06e-03	7.67e-04	3.62e-04	6.52e-04
Chromium	1.73e-06	1.72e-06	1.58e-06	1.67e-06	8.42e-08	2.37e-06
Copper	2.57e-05	1.29e-04	1.02e-04	8.56e-05	5.35e-05	8.89e-05
Lead	5.59e-04	6.22e-04	6.87e-04	6.23e-04	6.41e-05	7.11e-04
Mercury	-[e]	-	7.01e-09	< 7.01e-09	ND	1.54e-08
Nickel	1.52e-06	BDL	2.37e-06	<1.94e-06	ND	BDL
Potassium	4.88e-05	6.65e-05	8.00e-05	6.51e-05	1.56e-05	6.52e-05
Sodium	1.76e-05	6.76e-05	7.71e-05	5.41e-05	3.20e-05	2.85e-04
Titanium	1.57e-06	4.46e-06	4.47e-06	3.50e-06	1.67e-06	3.73e-06
Zinc	4.10e-05	6.16e-05	9.52e-05	6.59e-05	2.74e-05	3.97e-05

[a]Particulate matter less than ten microns in diameter.
[b]Average of Trials 1, 2, and 3.
[c]Below detection limit.
[d]Not determinable.
[e]Sample concentration became a negative value when corrected for background concentration.

Table 5.26. Emission Factors for Target Inorganic Gases from the Detonation of Composition B Surrogate.

Analyte	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)
Real-Time Analyzer					
CO_2	1.28e+00	1.23e+00	1.25e+00	1.25e+00	2.52e-02
CO	3.03e-03	4.21e-03	3.93e-03	3.72e-03	6.17e-04
NO	9.20e-03	8.93e-03	9.70e-03	9.28e-03	3.91e-04
NO_2	1.14e-04	1.66e-04	2.97e-04	1.92e-04	9.43e-05
SO_2	1.36e-04	1.37e-04	1.09e-04	1.27e-04	1.59e-05
SUMMA® Canister					
CO_2	1.14e+00	1.16e+00	1.11e+00	1.14e+00	2.52e-02
CO	3.42e-03	4.71e-03	4.39e-03	4.17e-03	6.72e-04

Table 5.27. Emission Factors for Total Nonmethane Organic Compounds (NMOCs) and Groups of Volatile Organic Compounds (VOCs) from the Detonation of Composition B Surrogate.

Analyte	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)
Alkanes (Paraffins)	1.27e-05	6.30e-06	1.53e-05	1.14e-05	4.63e-06
Alkenes (Olefins)	2.46e-05	2.33e-05	5.28e-05	3.36e-05	1.67e-05
Aromatics	1.71e-05	1.78e-05	3.57e-05	2.35e-05	1.05e-05
TUHCs[a]	3.72e-07	8.60e-05	4.99e-05	4.54e-05	4.30e-05
TNMHCs[b]	5.47e-05	1.33e-04	1.54e-04	1.14e-04	5.23e-05
Total NMOCs	2.90e-04	2.37e-04	3.43e-04	2.90e-04	5.27e-05

[a]Total unidentified hydrocarbons.
[b]Total nonmethane hydrocarbons.

Table 5.28. Emission Factors for 42-Component List of Volatile Organic Compounds (VOCs) from the Detonation of Composition B Surrogate.

Analyte	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)
Allyl chloride	BDL[a]	BDL	BDL	ND[b]	ND
Benzene	4.84e-06	4.82e-06	5.83e-06	5.16e-06	5.79e-07
Benzyl chloride	BDL	BDL	BDL	ND	ND
1,3-Butadiene	BDL	BDL	BDL	ND	ND
Carbon tetrachloride	-[c]	-	3.64e-07	< 3.64e-07	ND
Chlorobenzene	BDL	BDL	BDL	ND	ND
Chloroform	-	-	-	-	ND
1,2-Dibromoethane	BDL	BDL	BDL	ND	ND
m-Dichlorobenzene	BDL	BDL	BDL	ND	ND
o-Dichlorobenzene	BDL	BDL	BDL	ND	ND
p-Dichlorobenzene	BDL	BDL	BDL	ND	ND
1,1-Dichloroethane	BDL	BDL	BDL	ND	ND
1,2-Dichloroethane	BDL	BDL	BDL	ND	ND
cis-1,2-Dichloroethylene	BDL	BDL	BDL	ND	ND
Dichloromethane	-	3.71e-07	2.83e-04	< 1.42e-04	ND
1,2-Dichloropropane	BDL	BDL	BDL	ND	ND
cis-1,3-Dichloropropene	BDL	BDL	BDL	ND	ND
trans-1,3-Dichloropropene	BDL	BDL	BDL	ND	ND
Ethylbenzene	1.49e-06	1.48e-06	2.92e-06	1.96e-06	8.25e-07
Ethyl chloride	BDL	BDL	BDL	ND	ND
p-Ethyltoluene	7.44e-07	3.71e-07	1.09e-06	7.36e-07	3.61e-07
Freon® 11	1.12e-06	-	1.46e-06	< 1.29e-06	ND
Freon® 12	-	3.71e-07	-	< 3.71e-07	ND
Freon® 114	-	-	-	-	ND
Freon® 113	-	-	3.64e-07	< 3.64e-07	ND
Hexachlorobutadiene	BDL	BDL	BDL	ND	ND
Methyl bromide	BDL	BDL	BDL	ND	ND
Methyl chloride	7.44e-07	7.41e-07	7.29e-07	7.38e-07	8.21e-09
Methyl chloroform	-	-	-	-	ND
Styrene	BDL	BDL	BDL	ND	ND
1,1,2,2-Tetrachloroethane	BDL	BDL	BDL	ND	ND
Tetrachloroethylene	2.08e-05	1.89e-05	1.42e-05	1.80e-05	3.41e-06
Toluene	4.09e-06	1.48e-06	6.20e-06	3.92e-06	2.36e-06
1,2,4-Trichlorobenzene	BDL	BDL	BDL	ND	ND
1,1,2-Trichloroethane	BDL	BDL	BDL	ND	ND
Trichloroethylene	BDL	BDL	BDL	ND	ND
1,2,4-Trimethylbenzene	7.44e-07	3.71e-07	1.82e-06	9.79e-07	7.54e-07
1,3,5-Trimethylbenzene	-	3.71e-07	7.29e-07	< 5.50e-07	ND
m-, p-Xylene	5.58e-06	4.45e-06	1.02e-05	6.74e-06	3.05e-06
o-Xylene	1.86e-06	1.85e-06	4.37e-06	2.70e-06	1.45e-06
Vinyl chloride	BDL	BDL	BDL	ND	ND
Vinylidene chloride	BDL	BDL	BDL	ND	ND

[a]Below detection limit.

[b]Not determinable.

[c]Sample concentration became a negative value when corrected for background concentration.

Table 5.29. Emission Factors for Semivolatile Organic Compounds (SVOCs) (Sampled with High-Volume and PM_{10}[a] Samplers) from the Detonation of Composition B Surrogate.

Analyte	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)	PM_{10} Sampler Average[b] (g/g)
1,3,5-Trinitrobenzene	BDL[c]	2.02e-05	2.04e-06	<1.11e-05	ND[d]	2.48e-05
1,3-Dinitrobezene	BDL	BDL	3.38e-07	< 3.38e-07	ND	BDL
2,4-Dinitrotoluene	1.96e-07	3.92e-07	2.33e-07	2.74e-07	1.04e-07	3.04e-07
2-Mehtylnaphthalene	BDL	1.15e-07	BDL	<1.15e-07	ND	BDL
3,3'-Dimethylbenzidine	BDL	BDL	BDL	ND	ND	1.43e-07
Acetophenone	8.26e-08	2.23e-07	-[e]	< 1.53e-07	ND	3.35e-07
Benzyl alcohol	1.84e-07	4.10e-07	8.17e-08	2.25e-07	1.68e-07	2.23e-07
bis(2-Ethylhexyl) phthalate	1.32e-06	1.09e-06	2.37e-06	1.59e-06	6.85e-07	1.80e-06
Butylbenzyl phthalate	4.56e-07	4.96e-07	7.59e-07	5.70e-07	1.64e-07	6.14e-07
Di-n-butyl phthalate	1.21e-07	2.19e-07	1.79e-07	1.73e-07	4.92e-08	5.39e-07
Di-n-octyl phthalate	1.12e-06	1.52e-06	5.40e-06	2.68e-06	2.36e-06	2.29e-06
Diethyl phthalate	1.95e-08	9.16e-08	3.30e-07	1.47e-07	1.63e-07	4.90e-07
Dimethyl phthalate	2.47e-07	3.81e-07	3.85e-07	3.38e-07	7.85e-08	4.52e-07
Naphthalene	BDL	1.15e-07	BDL	< 1.15e-07	ND	BDL
Phenanthrene	7.60e-08	9.81e-08	9.34e-08	8.92e-08	1.16e-08	1.43e-07
Phenol	BDL	4.33e-07	BDL	< 4.33e-07	ND	BDL
Pyrene	BDL	BDL	7.59e-08	< 7.59e-08	ND	BDL

[a]Particulate matter less than ten microns in diameter.
[b]Average of trials 1, 2, and 3.
[c]Below detection limit.
[d]Not determinable.
[e]Sample concentration became a negative value when corrected for background concentration.

Table 5.30. Emission Factors for Semivolatile Organic Compounds (SVOCs) (Sampled with PS[a]-1 Samplers) from the Detonation of Composition B Surrogate.

Analyte	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)
Acetophenone	-[b]	-	3.26e-07	< 3.26e-07	ND[c]
Benzyl alcohol	1.61e-06	5.56e-06	9.51e-06	5.56e-06	3.95e-06
bis(2-Ethylhexyl) phthalate	9.18e-06	-	5.11e-06	< 7.14e-06	ND
Di-n-butyl phthalate	8.65e-07	-	-	< 8.65e-07	ND
Diethyl phthalate	-	-	-	ND	ND
Naphthalene	-	-	-	ND	ND
Phenol	4.54e-07	1.85e-06	2.41e-06	1.57e-06	1.01e-06

[a]Pesticide sampler.
[b]Sample concentration became a negative value when corrected for background concentration.
[c]Not determinable.

Table 5.31. Emission Factors for Metals from the Detonation of Composition B Surrogate.

Analyte	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)	PM_{10}[a] Sampler Average[b] (g/g)
Aluminum	2.02e-04	2.54e-04	3.10e-04	2.55e-04	5.45e-05	2.48e-04
Antimony	BDL[c]	BDL	BDL	ND[d]	ND	BDL
Arsenic	BDL	BDL	BDL	ND	ND	BDL
Barium	2.29e-04	2.59e-04	2.51e-04	2.47e-04	1.53e-05	2.67e-04
Cadmium	2.80e-06	3.26e-06	4.68e-06	3.58e-06	9.77e-07	4.03e-06
Calcium	6.83e-04	8.50e-04	9.99e-04	8.44e-04	1.58e-04	7.44e-04
Chromium	1.63e-06	1.68e-06	1.91e-06	1.74e-06	1.49e-07	3.66e-04
Copper	2.95e-04	3.27e-04	4.37e-04	3.53e-04	7.46e-05	3.66e-04
Lead	5.49e-04	5.47e-04	5.74e-04	5.57e-04	1.51e-05	6.20e-04
Mercury	6.36e-09	2.23e-09	3.55e-09	4.05e-09	2.11e-09	2.23e-08
Nickel	6.77e-07	1.02e-06	9.04e-07	8.67e-07	1.75e-07	1.18e-06
Potassium	5.84e-05	6.32e-05	7.44e-05	6.53e-05	8.24e-06	6.14e-05
Sodium	5.81e-06	7.01e-06	1.42e-05	9.01e-06	4.54e-06	1.86e-04
Titanium	4.28e-06	4.56e-06	6.32e-06	5.05e-06	1.11e-06	4.90e-06
Zinc	7.11e-05	7.09e-05	7.93e-05	7.38e-05	4.77e-06	6.20e-05

[a]Particulate matter less than ten microns in diameter.
[b]Average of trials 1, 2, and 3.
[c]Below detection limit.
[d]Not determinable.

5.2.6 Composition B Surrogate with Aluminum (HBX)

5.2.6.1 Target Inorganic Gases. The emission factors for target inorganic gases (measured with real-time analyzers or sampled with SUMMA® canisters and assayed using GC/FID) from the detonation of HBX are presented in Table 5.32.

5.2.6.2 Volatile Organic Compounds (VOCs)

a. The emission factors for total NMOCs and groups of Volatile Organic Compounds (VOCs) (sampled with SUMMA® canisters and assayed using GC/FID) from the detonation of HBX are presented in Table 5.33. The complete target list of VOCs is given in Paragraph 3.2.

b. The emission factors for the 42-component list of VOCs (sampled with SUMMA® canisters and assayed using GC/MS) from the detonation of HBX are presented in Table 5.34.

5.2.6.3 Semivolatile Organic Compounds (SVOCs)

a. The emission factors for SVOCs (sampled with high-volume and PM_{10} samplers and assayed using GC/MS) from the detonation of HBX are shown in Table 5.35. The complete target list of SVOCs is given in Paragraph 3.2.

b. The emission factors for SVOCs (sampled with PS-1 samplers and assayed using GC/MS) from the detonation of HBX are shown in Table 5.36.

5.2.6.4 Metals. The emission factors for metals (sampled with high-volume and PM_{10} samplers and assayed using ICP/OES and CVAA spectrometry) from the detonation of HBX are shown in Table 5.37.

5.2.6.5 Particulate Matter Less Than Ten Microns in Diameter (PM_{10}). The emission factors for PM_{10} from the detonation of HBX for trials 1, 2, and 3 are 6.79e-02 g/g, 3.74e-02 g/g, and 4.39e-01 g/g, respectively. The average is 1.81e-01 g/g with a standard deviation of 2.24e-01 g/g.

5.2.7 Tritonal Surrogate Surrounded by Water

5.2.7.1 Target Inorganic Gases. The emission factors for target inorganic gases (measured with real-time analyzers or sampled with SUMMA® canisters and assayed using GC/FID) from the detonation of tritonal surrogate surrounded by water are presented in Table 5.38.

5.2.7.2 Volatile Organic Compounds (VOCs)

a. The emission factors for total NMOCs and groups of VOCs (sampled with SUMMA® canisters and assayed using GC/FID) from the detonation of tritonal surrogate surrounded by water are presented in Table 5.39. The complete target list of VOCs is given in Paragraph 3.2.

b. The emission factors for the 42-component list of VOCs (sampled with SUMMA® canisters and assayed using GC/MS) from the detonation of tritonal surrogate surrounded by water are presented in Table 5.40.

Table 5.32. Emission Factors for Target Inorganic Gases from the Detonation of Composition B Surrogate with Aluminum (HBX).

Analyte	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)
Real-Time Analyzer					
CO_2	1.07e+00	1.16e+00	1.19e+00	1.14e+00	6.25e-02
CO	4.46e-03	3.36e-03	6.37e-03	4.73e-03	1.52e-03
NO	9.31e-03	9.83e-03	1.04e-02	9.85e-03	5.45e-04
NO_2	5.86e-05	4.02e-05	3.36e-05	4.41e-05	1.30e-05
SO_2	1.00e-04	1.12e-03	1.93e-03	1.05e-03	9.17e-04
SUMMA® Canister					
CO_2	9.65e-01	9.36e-01	1.12e+00	1.01e+00	9.89e-02
CO	4.35e-03	4.18e-03	7.02e-03	5.18e-03	1.59e-03

Table 5.33. Emission Factors for Total Nonmethane Organic Compounds (NMOCs) and Groups of Volatile Organic Compounds (VOCs) from the Detonation of Composition B Surrogate with Aluminum (HBX).

Analyte	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)
Alkanes (Paraffins)	2.52e-05	8.19e-07	1.71e-05	1.44e-05	1.24e-05
Alkenes (Olefins)	7.96e-05	6.72e-05	1.34e-04	9.35e-05	3.53e-05
Aromatics	-[a]	1.07e-05	3.08e-05	< 2.08e-05	ND[b]
TUHCs[c]	7.34e-05	-	8.35e-05	< 7.85e-05	ND
TNMHCs[d]	2.02e-04	7.66e-05	2.65e-04	1.81e-04	9.58e-05
Total NMOCs	4.35e-04	3.40e-04	5.16e-04	4.30e-04	8.79e-05

[a]Sample concentration became a negative value when corrected for background concentration.
[b]Not determinable.
[c]Total unidentified hydrocarbons.
[d]Total nonmethane hydrocarbons.

Table 5.34. Emission Factors for 42-Component List of Volatile Organic Compounds (VOCs) from the Detonation of Composition B Surrogate with Aluminum (HBX).

Analyte	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)
Allyl chloride	BDL[a]	BDL	BDL	ND[b]	ND
Benzene	5.48e-06	4.92e-06	1.08e-05	7.05e-06	2.63e-06
Benzyl chloride	BDL	BDL	BDL	ND	ND
1,3-Butadiene	BDL	BDL	BDL	ND	ND
Carbon tetrachloride	-[c]	4.10e-07	3.71e-07	<3.90e-07	ND
Chlorobenzene	BDL	BDL	BDL	ND	ND
Chloroform	3.65e-07	4.10e-07	3.71e-07	3.82e-07	1.97e-08
1,2-Dibromoethane	BDL	BDL	BDL	ND	ND
m-Dichlorobenzene	BDL	BDL	BDL	ND	ND
o-Dichlorobenzene	BDL	BDL	BDL	ND	ND
p-Dichlorobenzene	BDL	BDL	BDL	ND	ND
1,1-Dichloroethane	BDL	BDL	BDL	ND	ND
1,2-Dichloroethane	BDL	BDL	BDL	ND	ND
cis-1,2-Dichloroethylene	BDL	BDL	BDL	ND	ND
Dichloromethane	-	-	2.72e-04	< 2.72e-04	ND
1,2-Dichloropropane	BDL	BDL	BDL	ND	ND
cis-1,3-Dichloropropene	BDL	BDL	BDL	ND	ND
trans-1,3-Dichloropropene	BDL	BDL	BDL	ND	ND
Ethylbenzene	1.46e-06	2.46e-06	2.23e-06	2.05e-06	ND
Ethyl chloride	BDL	BDL	BDL	ND	ND
p-Ethyltoluene	3.65e-07	-	7.42e-07	< 5.55e-07	ND
Freon® 11	3.65e-07	4.10e-07	-	< 3.87e-07	ND
Freon® 12	-	-	3.71e-07	< 3.71e-07	ND
Freon® 114	-	-	-	-	ND
Freon® 113	-	-	-	-	ND
Hexachlorobutadiene	BDL	BDL	BDL	ND	ND
Methyl bromide	BDL	BDL	BDL	ND	ND
Methyl chloride	3.65e-07	4.10e-07	1.11e-06	6.29e-07	3.42e-07
Methyl chloroform	3.65e-07	4.10e-07	3.71e-07	3.82e-07	1.97e-08
Styrene	1.10e-06	BDL	1.85e-06	1.48e-06	3.79e-07
1,1,2,2-Tetrachloroethane	BDL	BDL	BDL	ND	ND
Tetrachloroethylene	BDL	BDL	BDL	ND	ND
Toluene	3.29e-06	1.64e-06	-	< 2.46-06	ND
1,2,4-Trichlorobenzene	BDL	BDL	BDL	ND	ND
1,1,2-Trichloroethane	BDL	BDL	BDL	ND	ND
Trichloroethylene	BDL	BDL	BDL	ND	ND
1,2,4-Trimethylbenzene	3.65e-07	-	1.11e-06	< 7.37e-07	4.63e-07
1,3,5-Trimethylbenzene	3.65e-07	-	-	< 3.65e-07	ND
m-, p-Xylene	4.75e-06	7.37e-06	5.19e-06	5.77e-06	1.15e-06
o-Xylene	1.83e-06	3.28e-06	2.60e-06	2.57e-06	5.93e-07
Vinyl chloride	BDL	BDL	BDL	ND	ND
Vinylidene chloride	BDL	BDL	BDL	ND	ND

[a]Below detection limit.

[b]Not determinable.

[c]Sample concentration became a negative value when corrected for background concentration.

Table 5.35. Emission Factors for Semivolatile Organic Compounds (SVOCs) (Sampled with High-Volume and PM_{10}[a] Samplers) from the Detonation of Composition B Surrogate with Aluminum (HBX).

Analyte	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)	PM_{10} Sampler Trial 3 (g/g)
1,3,5-Trinitrobenzene	BDL[b]	1.49e-05	5.98e-06	< 1.04e-05	ND[c]	BDL
2,4-Dinitrotoluene	2.23e-07	4.34e-07	3.38e-07	3.32e-07	1.05e-07	BDL
4-Aminobiphenyl	2.58e-07	BDL	BDL	< 2.58e-07	ND	BDL
4-Nitrophenol	BDL	BDL	6.50e-07	< 6.50e-07	ND	BDL
Acetophenone	2.51e-07	4.96e-07	3.83e-07	3.77e-07	1.22e-07	BDL
Benzyl alcohol	2.06e-07	4.34e-07	5.72e-07	4.04e-07	1.85e-07	BDL
bis(2-Ethylhexyl) phthalate	3.79e-06	-[d]	9.08e-06	< 6.44e-06	ND	3.18e-06
Butylbenzyl phthalate	1.03e-06	1.47e-06	3.38e-06	1.96e-06	1.25e-06	1.54e-06
Di-n-butyl phthalate	1.96e-06	1.32e-06	1.29e-06	1.53e-06	3.75e-07	1.03e-06
Di-n-octyl phthalate	2.91e-06	1.12e-05	1.65e-05	1.02e-05	6.86e-06	8.21e-06
Diethyl phthalate	2.83e-06	3.32e-06	2.32e-06	2.83e-06	4.98e-07	1.28e-06
Dimethyl phthalate	3.60e-07	6.74e-07	7.23e-07	5.86e-07	1.97e-07	4.52e-07
Phenanthrene	4.30e-07	5.06e-07	6.76e-07	5.37e-07	1.26e-07	BDL
Pyrene	1.72e-07	BDL	3.38e-07	< 2.55e-07	ND	BDL

[a]Particulate matter less than ten microns in diameter.
[b]Below detection limit.
[c]Not determinable.
[d]Sample concentration became a negative value when corrected for background concentration.

Table 5.36. Emission Factors for Semivolatile Organic Compounds (SVOCs) (Sampled with PS[a]-1 Samplers) from the Detonation of Composition B Surrogate with Aluminum (HBX).

Analyte	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)
Acetophenone	-[b]	3.97e-06	1.08e-05	< 7.38e-06	ND[c]
Benzyl alcohol	-	4.58e-05	3.33e-05	< 3.96e-05	ND
bis(2-Ethylhexyl) phthalate	4.26e-05	6.20e-06	1.49e-04	6.58e-05	7.40e-05
Di-n-butyl phthalate	5.24e-07	5.17e-05	1.65e-05	2.29e-05	2.62e-05
Diethyl phthalate	2.80e-07	9.71e-06	1.55e-05	8.48e-06	7.66e-06
Naphthalene	3.08e-07	3.23e-06	5.68e-06	3.07e-06	2.69e-06
Phenol	9.17e-08	1.18e-05	7.51e-06	6.46e-06	5.91e-06

[a]Pesticide sampler.
[b]Sample concentration became a negative value when corrected for background concentration.
[c]Not determinable.

Table 5.37. Emission Factors for Metals from the Detonation of Composition B Surrogate with Aluminum (HBX).

Analyte	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)	PM_{10}[a] Sampler Trial 3 (g/g)
Aluminum	6.86e-03	9.59e-03	1.15e-02	9.31e-03	2.33e-03	1.03e-02
Antimony	BDL[b]	BDL	BDL	ND[c]	ND	BDL
Arsenic	BDL	BDL	BDL	ND	ND	BDL
Barium	1.49e-04	2.28e-04	2.27e-04	2.01e-04	4.51e-05	1.90e-04
Cadmium	1.28e-06	2.99e-06	3.16e-06	2.47e-06	1.04e-06	2.51e-06
Calcium	1.95e-03	4.62e-03	6.35e-03	4.31e-03	2.22e-03	4.26e-03
Chromium	3.28e-06	7.59e-06	8.52e-06	6.46e-06	2.80e-06	5.65e-06
Copper	2.41e-03	4.97e-03	3.62e-03	3.67e-03	1.28e-03	3.34e-03
Lead	3.61e-05	5.57e-05	5.51e-05	4.90e-05	1.12e-05	4.31e-05
Mercury	7.08e-08	2.30e-07	8.65e-08	1.29e-07	8.77e-08	1.54e-07
Nickel	3.94e-06	9.62e-06	1.15e-05	8.36e-06	3.95e-06	9.24e-06
Potassium	1.34e-04	2.53e-04	3.46e-04	2.44e-04	1.06e-04	2.67e-04
Sodium	1.98e-04	3.81e-04	4.37e-04	3.39e-04	1.25e-04	1.39e-03
Titanium	1.15e-05	2.04e-05	3.14e-05	2.11e-05	9.96e-06	2.72e-05
Zinc	3.16e-04	5.93e-04	6.39e-04	5.16e-04	1.75e-04	5.65e-04

[a]Particulate matter less than ten microns in diameter.
[b]Below detection limit.
[c]Not determinable.

Table 5.38. Emission Factors for Target Inorganic Gases from the Detonation of Tritonal Surrogate Surrounded by Water.

Analyte	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)
Real-Time Analyzer					
CO_2	2.67e-01	4.07e-01	2.96e-01	3.23e-01	7.39e-02
CO	2.90e-01	2.25e-01	2.86e-01	2.67e-01	3.64e-02
NO	4.29e-03	3.90e-03	3.76e-03	3.98e-03	2.75e-04
NO_2	2.60e-04	1.54e-04	3.91e-04	2.68e-04	1.19e-04
SO_2	2.57e-05	5.69e-05	5.87e-05	4.71e-05	1.86e-05
SUMMA® Canister					
CO_2	2.45e-01	3.26e-01	2.60e-01	2.77e-01	4.31e-02
CO	2.82e-01	2.36e-01	2.76e-01	2.65e-01	2.50e-02

Table 5.39. Emission Factors for Total Nonmethane Organic Compounds (NMOCs) and Groups of Volatile Organic Compounds (VOCs) from the Detonation of Tritonal Surrogate Surrounded by Water.

Analyte	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)
Alkanes (Paraffins)	1.35e-04	1.60e-04	3.70e-04	2.22e-04	1.29e-04
Alkenes (Olefins)	5.89e-03	5.53e-03	6.14e-03	5.86e-03	3.04e-04
Aromatics	4.72e-04	1.82e-04	3.59e-04	3.38e-04	1.46e-04
TUHCs[a]	4.68e-04	5.99e-04	1.06e-03	7.08e-04	3.09e-04
TNMHCs[b]	6.97e-03	6.47e-03	7.93e-03	7.12e-03	7.39e-04
Total NMOCs	1.18e-02	8.88e-03	1.16e-02	1.08e-02	1.64e-03

[a]Total unidentified hydrocarbons.
[b]Total nonmethane hydrocarbons.

Table 5.40. Emission Factors for 42-Component List of Volatile Organic Compounds (VOCs) from the Detonation of Tritonal Surrogate Surrounded by Water.

Analyte	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)
Allyl chloride	BDL[a]	BDL	BDL	ND[b]	ND
Benzene	2.25e-04	9.73e-05	1.56e-04	1.60e-04	5.23e-05
Benzyl chloride	BDL	BDL	BDL	ND	ND
1,3-Butadiene	3.67e-05	6.72e-05	5.65e-05	5.34e-05	1.26e-05
Carbon tetrachloride	3.74e-07	3.67e-07	7.48e-07	4.97e-07	1.78e-07
Chlorobenzene	BDL	BDL	BDL	ND	ND
Chloroform	BDL	BDL	BDL	ND	ND
1,2-Dibromoethane	BDL	BDL	BDL	ND	ND
m-Dichlorobenzene	BDL	BDL	BDL	ND	ND
o-Dichlorobenzene	BDL	BDL	BDL	ND	ND
p-Dichlorobenzene	BDL	BDL	BDL	ND	ND
1,1-Dichloroethane	BDL	BDL	BDL	ND	ND
1,2-Dichloroethane	BDL	BDL	BDL	ND	ND
cis-1,2-Dichloroethylene	BDL	BDL	BDL	ND	ND
Dichloromethane	-[c]	8.81e-06	1.12e-06	< 4.96e-06	ND
1,2-Dichloropropane	BDL	BDL	BDL	ND	ND
cis-1,3-Dichloropropene	BDL	BDL	BDL	ND	ND
trans-1,3-Dichloropropene	BDL	BDL	BDL	ND	ND
Ethylbenzene	6.36e-06	4.04e-06	4.12e-06	4.84e-06	1.08e-06
Ethyl chloride	BDL	BDL	BDL	ND	ND
p-Ethyltoluene	1.12e-06	-	-	< 1.12e-06	ND
Freon® 11	-	-	-	-	ND
Freon® 12	4.12e-06	3.67e-06	3.74e-06	3.84e-06	1.96e-07
Freon® 114	BDL	BDL	BDL	ND	ND
Freon® 113	3.74e-07	2.94e-06	3.74e-07	1.23e-06	1.21e-06
Hexachlorobutadiene	BDL	BDL	BDL	ND	ND
Methyl bromide	BDL	BDL	BDL	ND	ND
Methyl chloride	3.74e-06	3.67e-06	4.12e-06	3.84e-06	1.95e-07
Methyl chloroform	3.74e-07	-	3.74e-07	< 3.74e-07	ND
Styrene	7.86e-06	4.40e-06	5.99e-06	6.08e-06	1.41e-06
1,1,2,2-Tetrachloroethane	BDL	BDL	BDL	ND	ND
Tetrachloroethylene	BDL	BDL	BDL	ND	ND
Toluene	1.03e-04	5.95e-05	6.55e-05	7.61e-05	1.94e-05
1,2,4-Trichlorobenzene	BDL	BDL	BDL	ND	ND
1,1,2-Trichloroethane	BDL	BDL	BDL	ND	ND
Trichloroethylene	BDL	BDL	BDL	ND	ND
1,2,4-Trimethylbenzene	1.50e-06	-	-	< 1.50e-06	ND
1,3,5-Trimethylbenzene	7.49e-07	-	3.74e-07	< 5.61e-07	ND
m-, p-Xylene	1.27e-05	1.06e-05	6.73e-06	1.00e-05	2.48e-06
o-Xylene	6.36e-06	4.77e-06	3.37e-06	4.83e-06	1.22e-06
Vinyl chloride	BDL	BDL	BDL	ND	ND
Vinylidene chloride	BDL	BDL	BDL	ND	ND

[a]Below detection limit.

[b]Not determinable.

[c]Sample concentration became a negative value when corrected for background concentration.

5.2.7.3 Semivolatile Organic Compounds (SVOCs)

a. The emission factors for SVOCs (sampled with high-volume and PM_{10} samplers and assayed using GC/MS) from the detonation of tritonal surrogate surrounded by water are presented in Table 5.41. The complete target list of SVOCs is given in Paragraph 3.2.

b. The emission factors for SVOCs (sampled with PS-1 samplers and assayed using GC/MS) from the detonation of tritonal surrogate surrounded by water are presented in Table 5.42.

5.2.7.4 Metals. The emission factors for metals (sampled with high-volume and PM_{10} samplers and assayed using ICP/OES and CVAA spectrometry) from the detonation of tritonal surrogate surrounded by water are presented in Table 5.43.

5.2.7.5 Particulate Matter Less Than Ten Microns in Diameter (PM_{10}). The emission factors for PM_{10} from the detonation of tritonal surrogate surrounded by water for trials 1, 2, and 3 are 1.12e-01 g/g, 2.22e-01 g/g, and 2.26e-01 g/g, respectively. The average is 1.87e-01 g/g with a standard deviation of 6.47e-02 g/g.

5.2.8 Detonation Residue

a. The residue remaining from the tritonal surrogate surrounded by water detonation trials was separated into two types based on physical appearance; one was designated as particulate and the other as plastic extract. Table 5.44 presents the mass of particulate and plastic extract detonation residue for each trial.

b. Table 5.45 shows the concentrations of SVOCs in the residue remaining from the three detonation of tritonal surrogate surrounded by water trials. The concentrations shown are the average concentration per trial.

c. Table 5.46 presents the concentrations of metals in the particulate residue remaining from the three detonation of tritonal surrogate surrounded by water trials. The concentrations shown are the average concentration per trial.

5.2.9 Manufacturer's Waste

5.2.10 Target Inorganic Gases. The emission factors for target inorganic gases (measured with real-time analyzers or sampled with SUMMA® canisters and assayed using GC/FID) from the burning of manufacturer's waste are presented in Table 5.47.

5.2.10.1 Volatile Organic Compounds (VOCs)

a. The emission factors for total NMOCs and groups of VOCs (sampled with SUMMA® canisters and assayed using GC/FID) from the burning of manufacturer's waste are presented in Table 5.48. The complete target list of VOCs is given in Paragraph 3.2.

b. The emission factors for the 42-component list of VOCs (sampled with SUMMA® canisters and assayed using GC/MS) from the burning of manufacturer's waste are presented in Table 5.49.

Table 5.41. Emission Factors for Semivolatile Organic Compounds (SVOCs) (Sampled with High-Volume and PM_{10}[a] Samplers) from the Detonation of Tritonal Surrogate Surrounded by Water.

Analyte	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)	PM_{10} Sampler Average[b] (g/g)
1,3,5-Trinitrobenzene	3.07e-05	1.46e-04	5.08e-05	7.59e-05	6.17e-05	2.14e-04
2,4-Dinitrotoluene	2.05e-05	1.86e-05	1.13e-05	1.68e-05	4.86e-06	5.27e-05
2,6-Dinitrotoluene	4.55e-06	3.85e-06	8.76e-07	3.09e-06	1.95e-06	9.56e-06
2-Mehtylnaphthalene	3.19e-06	2.26e-06	BDL[c]	< 2.72e-06	ND[d]	6.76e-06
3,3'-Dichlorobenzidine	BDL	BDL	BDL	ND	ND	2.64e-05
Acenaphthylene	4.21e-06	2.26e-06	1.78e-06	2.75e-06	1.29e-06	8.90e-06
Anthracene	9.90e-07	BDL	1.05e-06	< 1.02e-06	ND	BDL
Benzyl alcohol	1.06e-06	BDL	BDL	< 1.06e-06	ND	BDL
Biphenyl	2.05e-06	1.33e-06	BDL	< 1.69e-06	ND	4.28e-06
bis(2-Ethylhexyl) phthalate	3.59e-06	1.10e-05	1.33e-05	9.31e-06	5.09e-06	8.40e-06
Butylbenzyl phthalate	-[e]	3.40e-06	1.85e-06	< 2.62e-06	ND	1.12e-05
Di-n-butyl phthalate	-	-	1.57e-06	< 1.57e-06	ND	BDL
Di-n-octyl phthalate	2.63e-06	2.60e-05	4.39e-05	2.42e-05	2.07e-05	6.92e-05
Diethyl phthalate	1.55e-06	4.95e-06	1.01e-05	5.52e-06	4.28e-06	1.81e-05
Dimethyl phthalate	-	9.70e-07	-	< 9.70e-07	ND	BDL
Fluoranthrene	1.94e-06	BDL	2.16e-06	< 2.05e-06	ND	4.94e-06
Fluorene	1.94e-06	BDL	1.65e-06	< 1.79e-06	ND	4.78e-06
Naphthalene	5.12e-06	2.26e-06	1.40e-06	2.93e-06	1.95e-06	8.40e-06
Phenanthrene	4.10e-06	3.19e-06	4.82e-06	4.04e-06	8.19e-07	1.17e-05
Phenol	1.37e-06	1.33e-06	BDL	< 1.35e-06	ND	BDL
Pyrene	3.98e-06	2.92e-06	4.70e-06	3.87e-06	8.92e-07	BDL

[a]Particulate matter less than ten microns in diameter.
[b]Average of trials 1, 2, and 3.
[c]Below detection limit.
[d]Not determinable.
[e]Sample concentration became a negative value when corrected for background concentration.

Table 5.42. Emission Factors for Semivolatile Organic Compounds (SVOCs) (Sampled with PS[a]-1 Samplers) from the Detonation of Tritonal Surrogate Surrounded by Water.

Analyte	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)
1,3,5-Trinitrobenzene	BDL[b]	3.80e-05	1.88e-05	< 2.84e-05	ND[c]
2,4-Dinitrotoluene	4.17e-05	1.90e-05	2.75e-05	2.94e-05	1.15e-05
2-Methylnaphthalene	1.10e-05	7.42e-06	7.89e-06	8.76e-06	1.94e-06
3-Nitroaniline	BDL	6.29e-06	BDL	< 6.29e-06	ND
Acenaphthylene	1.25e-05	4.81e-06	1.09e-05	9.41e-06	4.05e-06
Acetophenone	-[d]	1.53e-07	3.46e-06	< 1.81e-06	ND
Anthracene	2.21e-06	BDL	BDL	< 2.21e-06	ND
Benzyl alcohol	-	2.01e-07	-	< 2.01e-07	ND
bis(2-Ethylhexyl) phthalate	4.41e-05	2.37e-05	8.63e-06	2.55e-05	1.78e-05
Butylbenzyl phthtalate	BDL	4.50e-06	5.58e-06	< 5.04e-06	ND
Di-n-butyl phthalate	-	-	-	-	ND
Diethyl phthalate	3.35e-06	6.21e-06	1.95e-05	9.69e-06	8.61e-06
Fluoranthene	2.97e-06	1.31e-06	2.16e-06	2.15e-06	8.30e-07
Fluorene	4.59e-06	BDL	3.94e-06	< 4.26e-06	ND
Naphthalene	4.55e-05	2.65e-05	3.57e-05	3.59e-05	9.52e-06
Phenanthrene	8.37e-06	4.19e-06	5.69e-06	6.09e-06	2.12e-06
Phenol	1.44e-05	1.39e-05	9.96e-06	1.28e-05	2.44e-06
Pyrene	6.38e-06	2.96e-06	4.12e-06	4.48e-06	1.74e-06

[a]Pesticide sampler.
[b]Below detection level.
[c]Not determinable.
[d]Sample concentration became a negative value when corrected for background concentration.

Table 5.43. Emission Factors for Metals from the Detonation of Tritonal Surrogate Surrounded by Water.

Analyte	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)	PM_{10}[a] Sampler Average[b] (g/g)
Aluminum	3.77e-03	7.69e-03	8.70e-03	6.72e-03	2.60e-03	7.91e-03
Antimony	BDL[c]	BDL	BDL	ND[d]	ND	BDL
Arsenic	BDL	BDL	BDL	ND	ND	BDL
Barium	1.34e-04	2.08e-04	2.11e-04	1.84e-04	4.37e-05	2.64e-04
Cadmium	5.14e-07	8.25e-07	1.13e-06	8.23e-07	3.08e-07	1.10e-06
Calcium	8.44e-04	1.71e-03	2.19e-03	1.58e-03	6.83e-04	2.14e-03
Chromium	3.26e-07	8.86e-07	1.90e-06	1.04e-06	7.96e-07	3.63e-06
Copper	1.40e-03	1.25e-03	1.44e-03	1.36e-03	9.91e-05	1.81e-03
Lead	2.19e-05	3.19e-05	2.82e-05	2.74e-05	5.09e-06	4.12e-05
Mercury	1.98e-08	5.05e-08	4.87e-08	3.96e-08	1.72e-08	2.14e-07
Nickel	2.59e-06	3.37e-06	3.27e-06	3.08e-06	4.24e-07	7.25e-06
Potassium	3.20e-05	1.04e-04	1.42e-04	9.28e-05	5.59e-05	1.48e-04
Sodium	7.38e-05	6.81e-04	9.42e-04	5.66e-04	4.45e-04	1.22e-03
Titanium	4.50e-06	7.81e-06	1.01e-05	7.47e-06	2.82e-06	9.56e-06
Zinc	2.57e-04	2.81e-04	2.97e-04	2.79e-04	2.00e-05	3.63e-04

[a]Particulate matter less than ten microns in diameter.
[b]Average of trials 1, 2, and 3.
[c]Below detection limit.
[d]Not determinable.

Table 5.44. Mass of Particulate and Plastic Extract in Residue Following Detonation of Tritonal Surrogate Surrounded by Water.

Trial	Particulate (g)	Plastic Extract (g)
1	10.31	0.65
2	16.76	0.80
3	12.14	0.89

Table 5.45. Concentrations of Semivolatile Organic Compounds (SVOCs) in the Tritonal Surrogate Surrounded by Water Detonation Residue.

Analyte	Particulate Average Per Trial (µg/kg)	Plastic Extract Average Per Trial (µg/kg)
2,6-Dinitrotoluene	117	BDL[a]
3-Nitroaniline	117	BDL
Acenaphthylene	117	BDL
bis(2-Ethylhexyl) phthalate	20,000	2067
Diethyl phthalate	2,033,333	213,333

[a]Below detection limit.

Table 5.46. Concentrations of Metals in the Tritonal Surrogate Surrounded by Water Detonation Residue.

Analyte	Particulate Average Per Trial (mg/kg)
Aluminum	4100
Antimony	BDL[a]
Arsenic	1.7
Barium	75.7
Cadmium	1.0
Calcium	18,667
Chromium	3.2
Copper	15,033
Lead	11
Mercury	0.13
Nickel	3.7
Potassium	2.98
Sodium	277
Titanium	25
Zinc	1577

[a]Below detection limit.

Table 5.47. Emission Factors for Target Inorganic Gases from the Burning of Manufacturer's Waste.

Analyte	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)
Real-Time Analyzer					
CO_2	7.75e-01	6.63e-01	8.61e-01	7.66e-01	9.93e-02
CO	1.37e-02	1.13e-02	1.67e-02	1.39e-02	2.71e-03
NO	9.26e-04	8.78e-04	1.24e-03	1.01e-03	1.97e-04
NO_2	4.40e-07	9.76e-06	9.67e-06	6.62e-06	5.36e-06
SO_2	8.57e-04	8.44e-04	8.76e-04	8.59e-04	1.61e-05
SUMMA® Canister					
CO_2	9.22e-01	8.49e-01	9.33e-01	9.01e-01	4.57e-02
CO	1.73e-02	1.49e-02	1.56e-02	1.59e-02	1.23e-03

Table 5.48. Emission Factors for Total Nonmethane Organic Compounds (NMOCs) and Groups of Volatile Organic Compounds (VOCs) from the Burning of Manufacturer's Waste.

Analyte	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)
Alkanes (Paraffins)	9.42e-05	5.75e-05	2.32e-04	1.28e-04	9.18e-05
Alkenes (Olefins)	2.19e-03	1.53e-03	1.86e-03	1.86e-03	3.31e-04
Aromatics	7.77e-04	3.64e-04	5.63e-04	5.68e-04	2.07e-04
TUHCs[a]	4.06e-04	2.26e-04	4.23e-04	3.52e-04	1.09e-04
TNMHCs[b]	3.47e-03	2.17e-03	3.08e-03	2.91e-03	6.64e-04
Total NMOCs	4.02e-03	2.18e-03	3.11e-03	3.10e-03	9.18e-04

[a]Total unidentified hydrocarbons.

[b]Total nonmethane hydrocarbons.

Table 5.49. Emission Factors for 42-Component List of Volatile Organic Compounds (VOCs) from the Burning of Manufacturer's Waste.

Analyte	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)
Allyl chloride	BDL[a]	BDL	BDL	ND[b]	ND
Benzene	2.91e-04	1.50e-04	1.88e-05	1.53e-04	1.11e-04
Benzyl chloride	BDL	BDL	BDL	ND	ND
1,3-Butadiene	-[c]	5.88e-06	-	< 5.88e-06	ND
Carbon tetrachloride	3.32e-06	6.34e-06	7.27e-06	5.64e-06	1.69e-06
Chlorobenzene	1.16e-05	8.01e-06	8.27e-06	9.30e-06	1.64e-06
Chloroform	2.19e-06	2.44e-06	2.30e-06	2.31e-06	1.04e-07
1,2-Dibromoethane	BDL	BDL	BDL	ND	ND
m-Dichlorobenzene	BDL	BDL	BDL	ND	ND
o-Dichlorobenzene	BDL	BDL	BDL	ND	ND
p-Dichlorobenzene	BDL	BDL	BDL	ND	ND
1,1-Dichloroethane	BDL	BDL	BDL	ND	ND
1,2-Dichloroethane	BDL	BDL	BDL	ND	ND
cis-1,2-Dichloroethylene	BDL	BDL	BDL	ND	ND
Dichloromethane	1.45e-05	9.77e-06	BDL	< 1.21e-05	ND
1,2-Dichloropropane	BDL	BDL	BDL	ND	ND
cis-1,3-Dichloropropene	BDL	BDL	BDL	ND	ND
trans-1,3-Dichloropropene	BDL	BDL	BDL	ND	ND
Ethylbenzene	1.58e-06	1.37e-06	2.07e-06	1.68e-06	2.90e-07
Ethyl chloride	BDL	BDL	BDL	ND	ND
p-Ethyltoluene	2.04e-06	1.98e-06	BDL	< 2.01e-06	ND
Freon® 11	3.77e-07	1.53e-07	0.00e+00	1.77e-07	1.55e-07
Freon® 12	9.06e-07	3.82e-07	6.89e-07	6.59e-07	2.15e-07
Freon® 114	-	-	-	-	ND
Freon® 113	7.55e-08	-	-	< 7.55e-08	ND
Hexachlorobutadiene	BDL	BDL	BDL	ND	ND
Methyl bromide	BDL	BDL	BDL	ND	ND
Methyl chloride	2.70e-05	1.40e-05	1.91e-05	2.01e-05	5.34e-06
Methyl chloroform	BDL	BDL	BDL	ND	ND
Styrene	1.00e-05	3.82e-06	3.06e-06	5.64e-06	3.13e-06
1,1,2,2-Tetrachloroethane	BDL	BDL	BDL	ND	ND
Tetrachloroethylene	BDL	1.60e-06	1.84e-06	< 1.72e-06	ND
Toluene	2.86e-05	1.93e-05	1.97e-05	2.25e-05	4.30e-06
1,2,4-Trichlorobenzene	BDL	BDL	BDL	ND	ND
1,1,2-Trichloroethane	BDL	BDL	BDL	ND	ND
Trichloroethylene	BDL	BDL	BDL	ND	ND
1,2,4-Trimethylbenzene	4.98e-06	3.82e-06	2.91e-06	3.90e-06	8.48e-07
1,3,5-Trimethylbenzene	1.96e-06	1.83e-06	3.60e-06	2.46e-06	8.03e-07
m-, p-Xylene	1.08e-05	BDL	1.32e-05	< 1.20e-05	ND
o-Xylene	3.40e-06	2.67e-06	4.36e-06	3.48e-06	6.93e-07
Vinyl chloride	BDL	BDL	BDL	ND	ND
Vinylidene chloride	BDL	BDL	BDL	ND	ND

[a]Below detection limit.

[b]Not determinable.

[c]Sample concentration became a negative value when corrected for background concentration.

5.2.10.2 Semivolatile Organic Compounds (SVOCs)

a. The emission factors for SVOCs (sampled with high-volume and PM_{10} samplers and assayed using GC/MS) from the burning of manufacturer's waste are presented in Table 5.50. The complete target list of SVOCs is given in Paragraph 3.2

b. The emission factors for SVOCs (sampled with PM_{10} samplers and assayed using GC/MS) from the burning of manufacturer's waste are presented in Table 5.51.

c. The emission factors for SVOCs (sampled with PS-1 samplers and assayed using GC/MS) from the burning of manufacturer's waste are presented in Table 5.52.

5.2.10.3 Metals

a. The emission factors for metals (sampled with high-volume samplers and assayed using ICP/OES and CVAA spectrometry) from the burning of manufacturer's waste are presented in Table 5.53.

b. The emission factors for metals (sampled with PM_{10} samplers and assayed using ICP/OES and CVAA spectrometry) from the burning of manufacturer's waste are presented in Table 5.54.

5.2.10.4 Particulate Matter Less Than Ten Microns in Diameter (PM_{10}). The emission factors for PM_{10} from the burning of manufacturer's waste for trials 1, 2, and 3 are 3.79e-01 g/g, 4.41e-01 g/g, and 4.90e+00 g/g, respectively. The average is 1.91e+00 g/g with a standard deviation of 2.59e+00 g/g.

5.2.10.5 Dioxins and Furans. Table 5.55 shows the emission factors for dioxins and furans (sampled with a PS-1 sampler and assayed using GC/MS) from the burning of manufacturer's waste.

5.2.10.6 Burn Pan Residue

a. The residue from each trial was separated into two types based on physical appearance: one was designated as ash and the other as wax. During Trials 2 and 3, the wax and some ash was lost in the pea gravel. Table 5.56 presents the mass of percent ash and wax in burn pan residue following burning of manufacturer's waste

b. Table 5.57 presents the concentrations of Semivolatile Organic Compounds (SVOCs) in the burn pan residue following the burning of manufacturer's waste.

c. Table 5.58 presents the concentrations of metals in the burn pan residue following the burning of manufacturer's waste.

5.2.10.7 Chlorine Recovered as HCl and Cl_2

a. The percent chlorine recovered as HCl and Cl_2 from the burning of manufacturer's waste is presented in Table 5.59.

b. The emission factors for HCl and Cl_2 from the burning of manufacturer's waste are presented in Table 5.60.

Table 5.50. Emission Factors for Semivolatile Organic Compounds (SVOCs) (Sampled with High-Volume Samplers) from the Burning of Manufacturer's Waste.

Analyte	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)
1,4-Naphthoquinone	3.59e-06	1.66e-06	BDL[a]	< 2.62e-06	ND[b]
Acenaphthalene	4.69e-07	9.85e-07	1.04e-04	3.52e-05	5.97e-05
Benzo(a)anthracene	1.08e-06	6.15e-07	1.64e-05	6.03e-06	8.99e-06
Benzo(a)pyrene	BDL	1.05e-06	2.16e-05	< 1.13e-05	ND
Benzo(b)fluoranthene	2.35e-06	1.26e-06	2.86e-05	1.07e-05	1.55e-05
Benzo(ghi)perylene	1.08e-06	1.38e-06	2.86e-05	1.04e-05	1.58e-05
Benzo(k)fluoranthene	3.59e-06	1.32e-06	3.65e-05	1.38e-05	1.97e-05
bis(2-Ethylhexyl) phthalate	BDL	7.46e-06	2.24e-05	< 1.49e-05	ND
Butylbenzyl phthalate	BDL	BDL	3.42e-06	< 3.42e-06	ND
Chrysene	3.04e-06	1.45e-06	3.38e-05	1.28e-05	1.83e-05
Di-n-octyl phthalate	2.56e-07	1.63e-05	1.31e-04	4.92e-05	7.13e-05
Dibenz(a,h)anthracene	3.04e-07	BDL	BDL	< 3.04e-07	ND
Diethyl phthalate	9.89e-09	-[c]	-	< 9.89e-09	ND
Fluoranthene	1.32e-04	8.62e-06	1.22e-04	8.78e-05	6.88e-05
Fluorene	BDL	3.69e-07	5.21e-06	< 2.79e-06	ND
Indeno(1,2,3-cd)pyrene	2.24e-06	1.14e-06	2.47e-05	9.37e-06	1.33e-05
Perylene	BDL	BDL	7.03e-06	< 7.03e-06	ND
Phenanthrene	6.07e-06	1.08e-05	1.87e-04	6.81e-05	1.03e-04
Pyrene	5.24e-06	6.77e-06	2.53e-04	8.82e-05	1.42e-04

[a]Below detection limit.

[b]Not determinable.

[c]Sample concentration became a negative value when corrected for background concentration.

5.2.11 Amatol Surrogate Surrounded by Water

5.2.11.1 Target Inorganic Gases. The emission factors for target inorganic gases (measured with real-time analyzers or sampled with SUMMA® canisters and assayed using GC/FID) from the detonation of amatol surrogate surrounded by water are presented in Table 5.61.

5.2.11.2 Volatile Organic Compounds (VOCs)

a. The emission factors for total NMOCs and groups of VOCs (sampled with SUMMA® canisters and assayed using GC/FID) from the detonation of amatol surrogate surrounded by water are presented in Table 5.62. The complete target list of VOCs is given in Paragraph 3.2.

b. The emission factors for the 42-component list of VOCs (sampled with SUMMA® canisters and assayed using GC/MS) from the detonation of amatol surrogate surrounded by water are presented in Table 5.63.

Table 5.51. Emission Factors for Semivolatile Organic Compounds (SVOCs) (Sampled with PM_{10}[a] Samplers) from the Burning of Manufacturer's Waste.

Analyte	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)
1,4-Naphthoquinone	3.01e-06	2.93e-06	BDL[b]	< 2.97e-06	ND[c]
Acenaphthylene	6.58e-07	1.82e-06	9.57e-06	4.02e-06	4.85e-06
Benzo(a)anthracene	2.31e-06	1.58e-06	2.36e-05	9.15e-06	1.25e-05
Benzo(a)pyrene	BDL	1.90e-06	2.72e-05	< 1.46e-05	ND
Benzo(b)fluoranthene	3.22e-06	2.14e-06	2.95e-05	1.16e-05	1.55e-05
Benzo(ghi)perylene	3.36e-06	3.01e-06	4.27e-05	1.64e-05	2.28e-05
Benzo(k)fluoranthene	4.20e-06	2.14e-06	3.02e-05	1.22e-05	1.56e-05
bis(2-Ethylhexyl) phthalate	1.68e-06	1.50e-05	1.47e-05	1.05e-05	7.62e-06
Chrysene	4.20e-06	2.45e-06	4.20e-05	1.62e-05	2.23e-05
Di-n-octyl phthalate	BDL	3.08e-05	5.89e-05	< 4.49e-05	ND
Dibenz(a,h)anthracene	BDL	BDL	6.92e-06	< 6.92e-06	ND
Diethyl phthalate	8.40e-07	BDL	BDL	< 8.40e-07	ND
Fluoranthene	1.75e-05	1.42e-05	2.14e-04	8.18e-05	1.14e-04
Fluorene	BDL	6.17e-07	6.41e-06	< 3.51e-06	ND
Indeno(1,2,3-cd)pyrene	3.15e-06	2.21e-06	3.46e-05	1.33e-05	1.84e-05
Phenanthrene	9.10e-06	1.66e-05	2.21e-04	8.22e-05	1.20e-04
Pyrene	1.19e-05	1.42e-05	1.62e-04	6.27e-05	8.60e-05

[a]Particulate matter less than ten microns in diameter.
[b]Below detection limit.
[c]Not determinable.

5.2.11.3 Semivolatile Organic Compounds (SVOCs)

a. The emission factors for SVOCs (sampled with high-volume and PM_{10} samplers and assayed using GC/MS) from the detonation of amatol surrogate surrounded by water are presented in Table 5.64. The complete target list of SVOCs is given in Paragraph 3.2.

b. The emission factors for SVOCs (sampled with PS-1 samplers and assayed using GC/MS) from the detonation of amatol surrogate surrounded by water are presented in Table 5.65.

5.2.11.4 Metals. The emission factors for metals (sampled with high-volume and PM_{10} samplers and assayed using ICP/OES and CVAA spectrometry) from the detonation of amatol surrogate surrounded by water are presented in Table 5.66.

5.2.11.5 Particulate Matter Less Than Ten Microns in Diameter (PM_{10}). The emission factors for PM_{10} from the detonation of amatol surrogate surrounded by water for trials 1, 2, and 3 are 2.36e-02 g/g, 3.11e-02 g/g, and 4.00e-02 g/g, respectively. The average is 3.16e-02 g/g with a standard deviation of 8.21e-03 g/g.

Table 5.52. Emission Factors for Semivolatile Organic Compounds (SVOCs) (Sampled with PS[a]-1 Samplers) from the Burning of Manufacturer's Waste.

Analyte	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)
2-Methylnaphthalene	1.24e-05	BDL[b]	BDL	< 1.24e-05	ND[c]
3-Nitroaniline	2.87e-05	BDL	BDL	< 2.87e-05	ND
Acenaphthylene	1.14e-04	4.99e-05	3.16e-04	1.60e-04	1.13e-04
Acetophenone	BDL	BDL	1.32e-04	< 1.32e-04	ND
Benzo(a)anthracene	4.36e-06	BDL	BDL	< 4.36e-06	ND
Benzo(b)fluoranthene	1.67e-05	BDL	9.86e-05	< 5.76e-05	ND
Benzyl alcohol	3.98e-07	-[d]	-	< 3.98e-07	ND
Biphenyl	1.83e-05	9.37e-06	9.02e-05	3.93e-05	3.62e-05
bis(2-Ethylhexyl) phthalate	8.22e-06	1.73e-05	-	< 1.28e-05	ND
Chrysene	9.58e-06	BDL	6.53e-05	< 3.74e-05	ND
Di-n-butyl phthalate	BDL	5.95e-05	3.75e-05	< 4.85e-05	ND
Di-n-octyl phthalate	BDL	5.00e-05	BDL	< 5.00e-05	ND
Dibenzofuran	4.69e-06	BDL	BDL	< 4.69e-06	ND
Diethyl phthalate	3.95e-06	3.42e-06	1.68e-05	8.07e-06	7.60e-06
Fluoranthene	4.96e-05	3.29e-05	3.56e-04	1.46e-04	1.82e-04
Fluorene	8.70e-06	BDL	4.38e-05	< 2.62e-05	ND
Naphthalene	2.98e-04	1.72e-04	1.89e-03	7.87e-04	9.58e-04
Phenanthrene	5.65e-05	4.54e-05	4.84e-04	1.95e-04	2.50e-04
Phenol	3.37e-05	2.17e-05	9.79e-05	5.11e-05	4.10e-05
Pyrene	2.07e-05	2.74e-05	2.86e-04	1.11e-04	1.51e-04

[a]Pesticide sampler.
[b]Below detection level.
[c]Not determinable.
[d]Sample concentration became a negative value when corrected for background concentration.

5.2.11.6 Detonation Residue

a. The residue remaining from the amatol surrogate surrounded by water detonation trials was separated into two types based on physical appearance; one was designated as particulate and the other as plastic extract. Table 5.67 presents the mass of particulate and plastic extract detonation residue for each trial.

b. Table 5.68 presents the concentrations of SVOCs in the residue remaining from the three detonation of amatol surrogate surrounded by water trials. The concentrations shown are the average concentration per trial.

c. Table 5.69 shows the concentrations of metals in the particulate residue remaining from the three detonation of amatol surrogate surrounded by water trials. The concentrations shown are the average concentration per trial.

Table 5.53. Emission Factors for Metals (Sampled with High-Volume Samplers) from the Burning of Manufacturer's Waste.

Analyte	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)
Aluminum	6.14e-03	8.53e-03	9.31e-02	3.59e-02	4.95e-02
Antimony	BDL[a]	4.95e-05	1.64e-04	< 1.07e-04	ND[b]
Arsenic	BDL	BDL	BDL	ND	ND
Barium	1.60e-05	1.95e-05	2.24e-04	8.63e-05	1.19e-04
Cadmium	BDL	BDL	BDL	ND	ND
Calcium	3.34e-04	5.60e-04	6.86e-03	2.59e-03	3.71e-03
Chromium	2.11e-06	2.06e-06	BDL	< 2.08e-06	ND
Copper	1.45e-05	-[c]	-	< 1.45e-05	ND
Lead	1.41e-05	7.33e-05	4.91e-04	1.93e-04	2.60e-04
Mercury	4.40e-08	4.96e-08	5.35e-07	2.10e-07	2.82e-07
Nickel	4.83e-06	BDL	BDL	< 4.83e-06	ND
Potassium	3.16e-04	5.37e-04	6.43e-03	2.43e-03	3.47e-03
Sodium	6.23e-04	6.61e-04	8.97e-03	3.42e-03	4.81e-03
Titanium	3.15e-06	2.02e-06	2.63e-05	1.05e-05	1.37e-05
Zinc	1.60e-04	1.11e-04	1.44e-03	5.71e-04	7.54e-04

[a]Below detection limit.
[b]Not determinable.
[c]Sample concentration became a negative value when corrected for background concentration.

5.2.12 Diesel Fuel and Dunnage

5.2.12.1 Target Inorganic Gases. The emission factors for target inorganic gases (measured with real-time analyzers or sampled with SUMMA® canisters and assayed using GC/FID) from the burninig of diesel fuel and dunnage are presented in Table 5.70.

5.2.12.2 Volatile Organic Compounds (VOCs)

a. The emission factors for total NMOCs and groups of VOCs (sampled with SUMMA® canisters and assayed using GC/FID) from the burning of diesel fuel and dunnage are presented in Table 5.71. The complete target list of VOCs is given in Paragraph 3.2.

b. The emission factors for the 42-component list of VOCs (sampled with SUMMA® canisters and assayed using GC/MS) from the burning of diesel fuel and dunnage are presented in Table 5.72.

Table 5.54. Emission Factors for Metals (Sampled with PM_{10}[a] Samplers) from the Burning of Manufacturer's Waste.

Analyte	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)
Aluminum	1.26e-02	1.50e-02	1.62e-01	6.32e-02	8.55e-02
Antimony	BDL[b]	4.98e-05	BDL	< 4.98e-05	ND[c]
Arsenic	BDL	BDL	BDL	ND	ND
Barium	3.22e-05	3.40e-05	3.46e-04	1.37e-04	1.81e-04
Cadmium	BDL	BDL	BDL	ND	ND
Calcium	8.40e-04	1.11e-03	1.25e-02	4.82e-03	6.67e-03
Chromium	5.60e-06	BDL	9.57e-05	< 5.07e-05	ND
Copper	5.81e-05	7.20e-05	6.92e-04	2.74e-04	3.62e-04
Lead	1.89e-05	9.49e-05	7.14e-04	2.76e-04	3.81e-04
Mercury	1.40e-07	7.91e-08	7.36e-07	3.18e-07	3.63e-07
Nickel	7.70e-06	BDL	7.36e-05	< 4.07e-05	ND
Potassium	5.39e-04	6.33e-04	8.84e-03	3.34e-03	4.76e-03
Sodium	1.89e-03	1.82e-03	2.06e-02	8.11e-03	1.08e-02
Titanium	2.45e-06	2.06e-06	3.09e-05	1.18e-05	1.66e-05
Zinc	2.38e-04	1.66e-04	1.99e-03	7.97e-04	1.03e-03

[a]Particulate matter less than ten microns in diameter.
[b]Below detection limit.
[c]Not determinable.

5.2.12.3 Semivolatile Organic Compounds (SVOCs)

a. The emission factors for SVOCs (sampled with high-volume and PM_{10} samplers and assayed using GC/MS) from the burning of diesel fuel and dunnage are presented in Table 5.73. The complete target list of SVOCs is given in Paragraph 3.2.

b. The emission factors for SVOCs (sampled with PS-1 samplers and assayed using GC/MS) from the burning of diesel and dunnage are presented in Table 5.74.

5.2.12.4 Metals. The emission factors for metals (sampled with high-volume and PM_{10} samplers and assayed using ICP/OES and CVAA spectrometry) from the burning of diesel and dunnage are presented in Table 5.75.

5.2.12.5 Particulate Matter Less Than Ten Microns in Diameter (PM_{10}). The emission factors for PM_{10} from the burning of diesel and dunnage for trials 1, 2, and 3 are 4.65e-03 g/g, 4.87e-03 g/g, and 6.79e-03 g/g, respectively. The average is 5.44e-03 g/g with a standard deviation of 1.18e-03 g/g.

5.2.12.6 Dioxins and Furans. The concentrations of dioxins and furans were measured during Trial 1. The only dioxin or furan detected was OCDD and its emission factor was calculated to be 1.03e-11 g/g.

Table 5.55. Emission Factors for Dioxins and Furans from the Burning of Manufacturer's Waste.

Analyte	Trial 3 (g/g)
Dioxins	
2378-tetrachlorinated dibenzo-*p*-dioxin (TCDD)	BDL[a]
1234678-heptachlorinated dibenzo-*p*-dioxin (HpCDD)	BDL
Octachlorinated dibenzo-*p*-dioxin (OCDD)	BDL
Furans	
2378-tetrachlorinated dibenzofuran (TCDF)	5.52e-09
12378-pentachlorinated dibenzofuran (PeCDF)	7.89e-09
23478-pentachlorinated dibenzofuran (PeCDF)	1.66e-08
123478-hexachlorinated dibenzofuran (HxCDF)	2.13e-08
123678-hexachlorinated dibenzofuran (HxCDF)	9.47e-09
234678-hexachlorinated dibenzofuran (HxCDF)	5.77e-09
1234678-heptachlorinated dibenzofuran (HpCDF)	3.42e-08
123478-heptachlorinated dibenzofuran (HpCDF)	7.89e-09
Octachlorinated dibenzofuran (OCDF)	3.95e-08

[a]Below detection limit.

Table 5.56. Percent Ash and Wax in Burn Pan Residue Following Burning of Manufacturer's Waste.

Trial	Ash (%)	Wax (%)
1	10.08	0.73
2	3.38	NA[a]
3	5.84	NA

[a]Not applicable (no sample was collected).

5.2.12.7 Burn Pan Residue

a. The mass of residue remaining in the burn pan following diesel fuel and dunnage burning Trials 1, 2, and 3, was 39.44 g, 42.77 g, and 49.16 g, respectively. Table 5.76 presents the concentrations of SVOCs in the residue.

b. Table 5.77 shows the concentrations of metals in the burn pan residue from the burning of diesel and dunnage.

Table 5.57. Concentrations of Semivolatile Organic Compounds (SVOCs) in the Manufacturer's Waste Burn Pan Residue.

Analyte	Ash Trial 1 (µg/kg)	Wax Trial 1 (µg/kg)	Composite of Trials 2 and 3 (µg/kg)
2-Methylnaphthalene	BDL[a]	BDL	870
Acenaphthylene	BDL	BDL	430
Acetophenone	BDL	BDL	490
Anthracene	BDL	BDL	190
Biphenyl	810	BDL	980
bis(2-Ethylhexyl) phthalate	830	6300	490
Butylbenzyl phthalate	BDL	BDL	95
Diethyl phthalate	BDL	BDL	92
Dimethoate	BDL	BDL	2700
Di-n-butyl phthalate	BDL	BDL	78
Di-n-octyl phthalate	BDL	6500	2400
Fluorene	BDL	BDL	160
Methyapyrilene	BDL	6000	500
Naphthalene	1700	BDL	3500
N-Nitrosodiphenylamine	BDL	BDL	2700
Phenanthrene	BDL	BDL	190
Phenol	BDL	BDL	360

[a]Below detection limit.

Table 5.58. Concentrations of Metals in the Manufacturer's Waste Burn Pan Residue.

Analyte	Ash Trial 1 (mg/kg)	Wax Trial 1 (mg/kg)	Composite of Trials 2 and 3 (mg/kg)
Aluminum	240,000	7600	380,000
Antimony	BDL[a]	BDL	15
Arsenic	BDL	BDL	BDL
Barium	20	0.9	15
Cadmium	BDL	BDL	BDL
Calcium	6200	320	5200
Chromium	780	1.3	7.6
Copper	57	41,000	980
Lead	21	BDL	71
Mercury	0.15	BDL	BDL
Nickel	610	6	30
Potassium	290	27	230
Sodium	370	190	280
Titanium	620	4.5	630
Zinc	2200	94	740

[a]Below detection limit.

Table 5.59. Percent Chlorine Recovered as HCl and Cl_2 from the Burning of Manufacturer's Waste.

Analyte	Sampling Train	Trial 1 (%)	Trial 2 (%)	Trial 3 (%)	Average (%)	Standard Deviation (%)
HCl	1	38.66	37.84	42.53	39.68	2.50
	2	43.62	36.07	42.38	40.69	4.05
Cl_2	1	0.10	0.01	0.07	0.06	0.05
	2	0.17	0.07	0.09	0.11	0.05

Table 5.60. Emission Factors for HCl and Cl_2 from the Burning of Manufacturer's Waste.

Analyte	Sampling Train	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)
HCl	1	8.01e-02	7.84e-02	8.82e-02	8.22e-02	5.24e-03
	2	9.04e-02	7.48e-02	8.78e-02	8.43e-02	8.36e-03
Cl_2	1	2.04e-04	3.01e-05	1.36e-04	1.23e-04	8.76e-05
	2	3.57e-04	-[a]	1.89e-04	<2.73e-04	ND[b]

[a]Sample concentration became a negative value when corrected for background concentration.
[b]Not determinable

Table 5.61. Emission Factors for Target Inorganic Gases from the Detonation of Amatol Surrogate Surrounded by Water.

Analyte	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)
Real-Time Analyzer					
CO_2	3.23e-01	3.25e-01	3.12e-01	3.20e-01	7.00e-03
CO	2.29e-01	2.29e-01	2.44e-01	2.34e-01	8.66e-03
NO	7.61e-03	7.52e-03	8.04e-03	7.72e-03	2.78e-04
NO_2	2.03e-04	2.10e-04	2.93e-04	2.35e-04	5.01e-05
SO_2	1.08e-04	1.74e-04	1.13e-04	1.32e-04	3.67e-05
SUMMA® Canister					
CO_2	3.22e-01	3.22e-01	2.71e-01	3.05e-01	2.94e-02
CO	2.44e-01	2.32e-01	2.45e-01	2.40e-01	7.23e-03

Table 5.62. Emission Factors for Total Nonmethane Organic Compounds (NMOCs) and Groups of Volatile Organic Compounds (VOCs) from the Detonation of Amatol Surrogate Surrounded by Water.

Analyte	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)
Alkanes (Paraffins)	1.12e-03	1.12e-03	1.38e-03	1.21e-03	1.52e-04
Alkenes (Olefins)	1.32e-03	1.42e-03	1.73e-03	1.49e-03	2.12e-04
Aromatics	3.30e-04	3.69e-04	4.81e-04	3.93e-04	7.83e-05
TUHCs[a]	8.10e-04	8.48e-04	4.33e-04	6.97e-04	2.29e-04
TNMHCs[b]	3.58e-03	3.76e-03	4.02e-03	3.79e-03	2.23e-04
Total NMOCs	4.50e-03	4.87e-03	5.49e-03	4.96e-03	4.98e-04

[a]Total unidentified hydrocarbons.
[b]Total nonmethane hydrocarbons.

Table 5.63. Emission Factors for 42-Component List of Volatile Organic Compounds (VOCs) from the Detonation of Amatol Surrogate Surrounded by Water.

Analyte	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)
Allyl chloride	BDL[a]	BDL	BDL	ND[b]	ND
Benzene	1.35e-04	1.45e-04	1.80e-04	1.54e-04	1.92e-05
Benzyl chloride	BDL	BDL	BDL	ND	ND
1,3-Butadiene	1.30e-05	1.36e-05	1.55e-05	1.40e-05	1.10e-06
Carbon tetrachloride	3.71e-07	3.66e-07	3.70e-07	3.69e-07	1.97e-09
Chlorobenzene	BDL	BDL	BDL	ND	ND
Chloroform	3.71e-07	3.66e-07	BDL	< 3.69e-07	ND
1,2-Dibromoethane	BDL	BDL	BDL	ND	ND
m-Dichlorobenzene	BDL	BDL	BDL	ND	ND
o-Dichlorobenzene	BDL	BDL	BDL	ND	ND
p-Dichlorobenzene	BDL	BDL	BDL	ND	ND
1,1-Dichloroethane	BDL	BDL	BDL	ND	ND
1,2-Dichloroethane	BDL	BDL	BDL	ND	ND
cis-1,2-Dichloroethylene	BDL	BDL	BDL	ND	ND
Dichloromethane	2.11e-04	2.01e-04	2.16e-04	2.09e-04	6.09e-06
1,2-Dichloropropane	BDL	BDL	BDL	ND	ND
cis-1,3-Dichloropropene	BDL	BDL	BDL	ND	ND
trans-1,3-Dichloropropene	BDL	BDL	BDL	ND	ND
Ethylbenzene	1.04e-05	1.14e-05	1.22e-05	1.13e-05	7.46e-07
Ethyl chloride	BDL	BDL	BDL	ND	ND
p-Ethyltoluene	2.23e-06	2.20e-06	1.85e-06	2.09e-06	1.71e-07
Freon® 11	3.71e-07	7.33e-07	7.40e-07	6.15e-07	1.72e-07
Freon® 12	4.82e-06	3.66e-06	4.44e-06	4.31e-06	4.82e-07
Freon® 114	-[c]	-	-	-	ND
Freon® 113	-	-	-	-	ND
Hexachlorobutadiene	BDL	BDL	BDL	ND	ND
Methyl bromide	BDL	BDL	BDL	ND	ND
Methyl chloride	2.23e-06	1.83e-06	2.59e-06	2.22e-06	3.10e-07
Methyl chloroform	3.71e-07	-	3.70e-07	<3.71e-07	ND
Styrene	BDL	3.66e-06	3.70e-06	<3.68e-06	ND
1,1,2,2-Tetrachloroethane	BDL	BDL	BDL	ND	ND
Tetrachloroethylene	BDL	BDL	BDL	ND	ND
Toluene	4.79e-05	6.49e-05	1.48e-06	3.81e-05	2.68e-05
1,2,4-Trichlorobenzene	BDL	BDL	BDL	ND	ND
1,1,2-Trichloroethane	BDL	BDL	BDL	ND	ND
Trichloroethylene	BDL	BDL	BDL	ND	ND
1,2,4-Trimethylbenzene	1.11e-06	1.47e-06	1.11e-06	1.23e-06	1.67e-07
1,3,5-Trimethylbenzene	3.71e-07	3.66e-07	3.70e-07	3.69e-07	1.97e-09
m-, p-Xylene	1.08e-05	1.28e-05	1.37e-05	1.24e-05	1.23e-06
o-Xylene	5.94e-06	6.60e-06	7.03e-06	6.52e-06	4.51e-07
Vinyl chloride	BDL	BDL	BDL	ND	ND
Vinylidene chloride	BDL	BDL	BDL	ND	ND

[a]Below detection limit.

[b]Not determinable.

[c]Sample concentration became a negative value when corrected for background concentration.

Table 5.64. Emission Factors for Semivolatile Organic Compounds (SVOCs) (Sampled with High-Volume and PM_{10}[a] Samplers) from the Detonation of Amatol Surrogate Surrounded by Water.

Analyte	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)	PM_{10} Sampler Average[b] (g/g)
1,3,5-Trinitrobenzene	6.15e-06	1.10e-05	1.02e-05	9.11e-06	2.59e-06	2.33e-05
2,4-Dinitrotoluene	1.11e-06	1.16e-06	1.46e-06	1.24e-06	1.90e-07	2.54e-06
2,6-Dinitrotoluene	2.89e-07	1.47e-07	4.06e-07	2.81e-07	1.30e-07	4.14e-07
2-Methylnaphthalene	6.15e-08	1.47e-07	1.27e-07	1.12e-07	4.46e-08	5.02e-07
3- and 4-Methylphenol (m- and p-Cresol)	1.42e-07	7.95e-08	7.62e-08	9.91e-08	3.68e-08	1.74e-07
4-Aminobiphenyl	BDL[c]	BDL	BDL	ND[d]	ND	3.78e-07
4-Nitrophenol	2.52e-07	2.75e-07	2.92e-07	2.73e-07	1.99e-08	8.72e-07
Acenaphthene	7.39e-08	BDL	BDL	< 7.39e-08	ND	BDL
Acenaphthylene	5.11e-07	3.85e-07	3.62e-07	4.19e-07	8.01e-08	8.72e-07
Acetophenone	-[e]	-	1.96e-08	< 1.96e-08	ND	2.76e-07
Anthracene	1.05e-07	1.47e-07	2.22e-07	1.58e-07	5.96e-08	2.98e-07
Benzo(a)anthracene	BDL	BDL	1.78e-07	< 1.78e-07	ND	2.47e-07
Benzo(a)pyrene	BDL	BDL	7.62e-08	< 7.62e-08	ND	BDL
Benzyl alcohol	5.35e-07	1.65e-07	1.33e-07	2.78e-07	2.24e-07	5.31e-07
Biphenyl	3.51e-07	1.41e-07	1.40e-07	2.10e-07	1.22e-07	4.07e-07
bis(2-Ethylhexyl) phthalate	2.54e-06	2.34e-06	3.64e-06	2.84e-06	6.99e-07	6.11e-06
Butylbenzyl phthalate	6.15e-07	7.34e-07	1.21e-06	8.52e-07	3.12e-07	1.89e-06
Chrysene	6.77e-08	BDL	1.46e-07	< 1.07e-07	ND	2.54e-07
Di-n-butyl phthalate	1.30e-07	2.68e-07	3.93e-07	2.64e-07	1.31e-07	1.09e-06
Di-n-octyl phthalate	4.83e-06	4.26e-06	7.40e-06	5.50e-06	1.68e-06	1.16e-05
Diethyl phthalate	9.64e-07	3.47e-06	4.43e-06	2.95e-06	1.79e-06	6.33e-06
Dimethyl phthalate	6.52e-08	1.66e-07	2.81e-07	1.71e-07	1.08e-07	6.98e-07
Fluoanthene	4.00e-07	6.73e-07	1.02e-06	6.96e-07	3.09e-07	1.45e-06
Fluorene	2.59e-07	2.39e-07	2.79e-08	1.75e-07	1.28e-07	5.16e-07
Naphthalene	6.15e-07	2.33e-07	3.11e-07	3.86e-07	2.02e-07	5.89e-07
Perylene	BDL	BDL	1.08e-07	< 1.08e-07	ND	BDL
Phenanthrene	8.62e-07	1.47e-06	2.10e-06	1.48e-06	6.17e-07	2.98e-06
Phenol	7.39e-07	2.69e-07	BDL	< 5.04e-07	ND	7.27e-07
Pyrene	7.39e-07	1.10e-06	1.90e-06	1.25e-06	5.97e-07	2.33e-06

[a]Particulate matter less than ten microns in diameter.
[b]Average of trials 1, 2, and 3.
[c]Below detection limit.
[d]Not determinable.
[e]Sample concentration became a negative value when corrected for background concentration.

Table 5.65. Emission Factors for Semivolatile Organic Compounds (SVOCs) (Sampled with PS[a]-1 Samplers) from the Detonation of Amatol Surrogate Surrounded by Water.

Analyte	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)
2,4-Dinitrotoluene	BDL[b]	2.53e-06	4.09e-06	< 3.31e-06	ND[c]
2-Methylnaphthalene	4.21e-06	4.88e-06	6.86e-06	5.31e-06	1.38e-06
Acenaphthylene	1.76e-06	2.13e-06	3.29e-06	2.39e-06	7.95e-07
Acetophenone	8.61e-06	8.71e-06	1.10e-05	9.42e-06	1.33e-06
Benzyl alcohol	6.46e-06	1.56e-05	2.04e-05	1.42e-05	7.09e-06
Biphenyl	2.02e-06	2.48e-06	3.24e-06	2.58e-06	6.13e-07
bis(2-Ethylhexyl) phthalate	5.95e-06	6.04e-06	8.58e-06	6.86e-06	1.49e-06
Butylbenzyl phthalate	BDL	1.80e-06	2.90e-06	< 2.35e-06	ND
Di-n-butyl phthalate	6.62e-06	-[d]	2.47e-06	< 4.54e-06	ND
Di-n-octyl phthalate	1.00e-05	BDL	8.98e-06	< 9.49e-06	ND
Diethyl phthalate	1.96e-06	9.28e-06	1.29e-05	8.06e-06	5.59e-06
Naphthalene	1.43e-05	2.03e-05	3.08e-05	2.18e-05	8.35e-06
Phenanthrene	1.72e-06	2.73e-06	4.10e-06	2.85e-06	1.20e-06
Phenol	3.87e-06	9.03e-06	1.20e-05	8.29e-06	4.10e-06
Pyrene	1.15e-06	BDL	BDL	< 1.15e-06	ND

[a]Pesticide sampler.
[b]Below detection level.
[c]Not determinable.
[d]Sample concentration became a negative value when corrected for background concentration.

Table 5.66. Emission Factors for Metals from the Detonation of Amatol Surrogate Surrounded by Water.

Analyte	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)	PM_{10}[a] Sampler Average[b] (g/g)
Aluminum	4.07e-04	3.21e-04	2.61e-04	3.29e-04	7.33e-05	3.93e-04
Antimony	BDL[c]	BDL	BDL	ND[d]	ND	BDL
Arsenic	BDL	BDL	BDL	ND	ND	BDL
Barium	9.83e-05	1.07e-04	1.16e-04	1.07e-04	9.11e-06	1.24e-04
Cadmium	5.82e-07	4.78e-07	4.02e-07	4.87e-07	9.01e-08	4.65e-07
Calcium	3.36e-04	5.42e-04	8.15e-04	5.64e-04	2.41e-04	6.47e-04
Chromium	1.63e-06	1.44e-06	1.66e-06	1.58e-06	1.15e-07	2.69e-06
Copper	1.58e-05	6.87e-05	2.32e-04	1.05e-04	1.13e-04	2.47e-04
Lead	6.63e-05	4.45e-05	3.19e-05	4.76e-05	1.74e-05	4.87e-05
Mercury	2.57e-08	1.45e-08	8.41e-09	1.62e-08	8.77e-09	1.45e-08
Nickel	8.26e-07	1.44e-06	9.46e-07	1.07e-06	3.28e-07	1.60e-06
Potassium	4.19e-05	5.78e-05	9.11e-05	6.36e-05	2.51e-05	7.20e-05
Sodium	4.10e-04	4.90e-04	6.68e-04	5.23e-04	1.32e-04	7.27e-04
Titanium	1.81e-06	2.62e-06	3.26e-06	2.56e-06	7.27e-07	2.62e-06
Zinc	3.97e-05	5.01e-05	7.48e-05	5.48e-05	1.80e-05	5.74e-05

[a]Particulate matter less than ten microns in diameter.
[b]Average of trials 1, 2, and 3.
[c]Below detection limit.
[d]Not determinable.

Table 5.67. Mass of Particulate and Plastic Extract in Residue Following Detonation of Amatol Surrogate Surrounded by Water.

Trial	Particulate (g)	Plastic Extract (g)
1	3.23	0.24
2	6.79	0.50
3	4.63	0.31

Table 5.68. Concentrations of Semivolatile Organic Compounds (SVOCs) in the Amatol Surrogate Surrounded by Water Detonation Residue.

Analyte	Particulate Average Per Trial (µg/kg)	Plastic Extract Average Per Trial (µg/kg)
2,6-Dinitrotoluene	2333	BDL[a]
Benzo(a)pyrene	1967	BDL
Benzyl alcohol	15,667	BDL
bis(2-Ethylhexyl) phthalate	5667	BDL
Diethyl phthalate	150,000	4,333,333
Di-n-octyl phthalate	1500	BDL

[a]Below detection limit.

Table 5.69. Concentrations of Metals in the Amatol Surrogate Surrounded by Water Detonation Residue.

Analyte	Particulate Average Per Trial (mg/kg)
Aluminum	11,667
Antimony	BDL[a]
Arsenic	BDL
Barium	47
Cadmium	2.8
Calcium	22,667
Chromium	6
Copper	46.667
Lead	36.7
Mercury	0.19
Nickel	9.3
Potassium	767
Sodium	567
Titanium	47
Zinc	3133

[a]Below detection limit.

Table 5.70. Emission Factors for Target Inorganic Gases from the Burning of Diesel Fuel and Dunnage.

Analyte	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)
Real-Time Analyzer					
CO_2	1.58e+00	1.64e+00	1.66e+00	1.63e+00	4.16e-02
CO	2.73e-02	2.93e-02	3.29e-02	2.98e-02	2.84e-03
NO	6.26e-04	8.94e-04	8.76e-04	7.99e-04	1.50e-04
NO_2	-[a]	5.07e-05	3.24e-05	< 4.15e-05	ND[b]
SO_2	2.07e-04	7.91e-05	2.77e-04	1.88e-04	1.00e-04
SUMMA® Canister					
CO_2	1.48e+00	1.51e+00	1.49e+00	1.49e+00	1.53e-02
CO	7.35e-03	4.70e-03	5.96e-03	6.00e-03	1.33e-03

[a]Sample concentration became a negative value when corrected for background.
[b]Not determinable.

Table 5.71. Emission Factors for Total Nonmethane Organic Compounds (NMOCs) and Groups of Volatile Organic Compounds (VOCs) from the Burning of Diesel Fuel and Dunnage.

Analyte	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)
Alkanes (Paraffins)	2.66e-03	3.90e-03	3.92e-03	3.50e-03	7.24e-04
Alkenes (Olefins)	2.00e-04	1.73e-04	2.07e-04	1.93e-04	1.81e-05
Aromatics	1.55e-03	2.73e-03	2.61e-03	2.29e-03	6.50e-04
TUHCs[a]	5.53e-03	6.02e-03	6.58e-03	6.04e-03	5.26e-04
TNMHCs[b]	9.94e-03	1.28e-02	1.33e-02	1.20e-02	1.83e-03
Total NMOCs	1.04e-02	1.29e-02	1.35e-04	7.84e-03	6.79e-03

[a]Total unidentified hydrocarbons.
[b]Total nonmethane hydrocarbons.

Table 5.72. Emission Factors for 42-Component List of Volatile Organic Compounds (VOCs) from the Burning of Diesel Fuel and Dunnage.

Analyte	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)
Allyl chloride	BDL[a]	BDL	BDL	ND[b]	ND
Benzene	8.41e-05	2.87e-07	3.93e-07	2.83e-05	4.84e-05
Benzyl chloride	BDL	BDL	BDL	ND	ND
1,3-Butadiene	BDL	BDL	BDL	ND	ND
Carbon tetrachloride	BDL	BDL	-[c]	-	ND
Chlorobenzene	BDL	BDL	BDL	ND	ND
Chloroform	BDL	BDL	BDL	ND	ND
1,2-Dibromoethane	BDL	BDL	BDL	ND	ND
m-Dichlorobenzene	BDL	BDL	BDL	ND	ND
o-Dichlorobenzene	BDL	BDL	BDL	ND	ND
p-Dichlorobenzene	BDL	BDL	BDL	ND	ND
1,1-Dichloroethane	BDL	BDL	BDL	ND	ND
1,2-Dichloroethane	BDL	BDL	BDL	ND	ND
cis-1,2-Dichloroethylene	BDL	BDL	BDL	ND	ND
Dichloromethane	BDL	BDL	BDL	ND	ND
1,2-Dichloropropane	BDL	BDL	BDL	ND	ND
cis-1,3-Dichloropropene	BDL	BDL	BDL	ND	ND
trans-1,3-Dichloropropene	BDL	BDL	BDL	ND	ND
Ethylbenzene	3.11e-05	1.44e-06	9.83e-08	1.09e-05	1.75e-05
Ethyl chloride	BDL	BDL	BDL	ND	ND
p-Ethyltoluene	1.15e-04	6.60e-06	6.88e-07	4.08e-05	5.26e-05
Freon® 11	-	-	-	-	ND
Freon® 12	1.69e-06	-	2.95e-07	< 9.93e-07	ND
Freon® 114	BDL	BDL	-	-	ND
Freon® 113	1.88e-07	-	-	<1.88e-07	ND
Hexachlorobutadiene	BDL	BDL	BDL	ND	ND
Methyl bromide	BDL	BDL	BDL	ND	ND
Methyl chloride	BDL	BDL	BDL	ND	ND
Methyl chloroform	BDL	BDL	-	-	ND
Styrene	4.99e-05	BDL	-	< 4.99e-05	ND
1,1,2,2-Tetrachloroethane	BDL	BDL	BDL	ND	ND
Tetrachloroethylene	BDL	BDL	BDL	ND	ND
Toluene	7.25e-05	1.34e-06	1.97e-07	2.47e-05	4.14e-05
1,2,4-Trichlorobenzene	BDL	BDL	BDL	ND	ND
1,1,2-Trichloroethane	BDL	BDL	BDL	ND	ND
Trichloroethylene	BDL	BDL	BDL	ND	ND
1,2,4-Trimethylbenzene	2.43e-04	1.30e-05	-	< 1.28e-04	ND
1,3,5-Trimethylbenzene	1.33e-04	7.75e-06	8.84e-07	4.74e-05	6.09e-05
m-, p-Xylene	2.24e-04	1.33e-05	3.34e-06	8.01e-05	1.24e-04
o-Xylene	8.58e-05	5.84e-06	6.96e-05	5.37e-05	3.45e-05
Vinyl chloride	BDL	BDL	BDL	ND	ND
Vinylidene chloride	BDL	BDL	BDL	ND	ND

[a]Below detection limit.

[b]Not determinable.

[c]Sample concentration became a negative value when corrected for background concentration.

Table 5.73. Emission Factors for Semivolatile Organic Compounds (SVOCs) (Sampled with High-Volume and PM_{10}[a] Samplers) from the Burning of Diesel Fuel and Dunnage.

Analyte	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)	PM_{10} Sampler Trial 1 (g/g)	PM_{10} Sampler Average[b] (g/g)
2-Methylphenol (o-Cresol)	BDL[c]	BDL	3.92e-08	< 3.92e-08	ND[d]	BDL	BDL
Acenaphthylene	BDL	BDL	4.71e-08	< 4.71e-08	ND	BDL	BDL
Acetophenone	5.12e-08	1.74e-07	BDL	< 1.13e-07	ND	BDL	2.43e-07
Anthracene	-[e]	6.40e-08	1.02e-07	< 8.30e-08	ND	BDL	1.43e-07
Benzo(a)anthracene	-	2.77e-07	9.81e-07	< 6.29e-07	ND	5.38e-07	1.62e-06
Benzo(a)pyrene	6.56e-07	7.47e-07	8.24e-07	7.42e-07	8.41e-08	4.82e-07	1.25e-06
Benzo(b)fluoranthene	8.98e-07	3.56e-07	1.10e-06	7.84e-07	3.84e-07	5.38e-07	1.31e-06
Benzo(ghi)perylene	3.45e-07	BDL	2.20e-07	< 2.82e-07	ND	2.24e-07	BDL
Benzo(k)fluoranthene	5.87e-07	BDL	7.46e-07	< 6.66e-07	ND	3.92e-07	9.98e-07
Biphenyl	3.80e-08	BDL	5.89e-08	< 4.84e-08	ND	BDL	BDL
bis(2-Ethylhexyl) phthalate	-	-	-	-	ND	2.13e-06	1.31e-07
Butylbenzyl phthalate	-	8.18e-08	1.22e-07	< 1.02e-07	ND	BDL	2.18e-07
Chrysene	1.21e-06	2.95e-07	1.29e-06	9.33e-07	5.54e-07	7.18e-07	1.75e-06
Di-n-butyl phthalate	-	1.46e-07	1.26e-07	< 1.36e-07	ND	1.91e-07	2.31e-07
Di-n-octyl phthalate	-	2.73e-07	9.19e-07	< 5.96e-07	ND	4.37e-07	1.43e-06
Dibenz(a,h)anthracene	2.00e-07	3.91e-07	1.53e-07	2.48e-07	1.26e-07	1.12e-07	2.06e-07
Dibenzofuran	BDL	BDL	4.71e-08	< 4.71e-08	ND	BDL	BDL
Diethyl phthalate	1.94e-08	3.84e-08	7.00e-08	4.26e-08	2.55e-08	1.08e-07	1.62e-07
Dimethyl phthalate	3.02e-08	BDL	1.88e-07	< 1.09e-07	ND	BDL	BDL
Fluoranthene	-	4.62e-07	7.85e-07	< 6.23e-07	ND	3.92e-07	1.06e-06
Indeno(1,2,3-cd)pyrene	4.49e-07	1.10e-07	2.90e-07	2.83e-07	1.69e-07	2.58e-07	1.81e-07
Perylene	2.00e-07	1.10e-07	2.04e-07	1.72e-07	5.31e-08	1.35e-07	2.50e-07
Phenanthrene	2.18e-07	2.42e-07	3.81e-07	2.80e-07	8.80e-08	1.57e-07	5.74e-07
Pyrene	-	4.62e-07	7.06e-07	< 5.84e-07	ND	3.14e-07	1.06e-06

[a]Particulate matter less than ten microns in diameter.

[b]Average of trials 2 and 3.

[c]Below detection limit.

[d]Not determinable.

[e]Sample concentration became a negative value when corrected for background concentration.

Table 5.74. Emission Factors for Semivolatile Organic Compounds (SVOCs) (Sampled with PS[a]-1 Samplers) from the Burning of Diesel Fuel and Dunnage.

Analyte	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)
2-Methylnaphthalene	2.20e-05	2.04e-05	2.31e-05	2.18e-05	1.32e-06
Acenaphthylene	4.57e-06	3.49e-06	6.71e-06	4.92e-06	1.64e-06
Benzo(a)anthracene	1.27e-06	BDL[b]	1.62e-06	< 1.44e-06	ND[c]
Benzo(b)fluoranthene	1.77e-06	9.66e-07	2.04e-06	1.59e-06	5.57e-07
Biphenyl	5.05e-06	5.41e-06	8.88e-06	6.45e-06	2.11e-06
bis(2-Ethylhexyl) phthalate	-[d]	1.98e-07	8.59e-07	< 5.28e-07	ND
Chrysene	BDL	8.73e-07	BDL	< 8.73e-07	ND
Di-n-butyl phthalate	-	BDL	1.77e-06	< 1.77e-06	ND
Di-n-octyl phthalate	7.93e-07	BDL	1.13e-06	< 9.61e-07	ND
Dibenzofuran	1.31e-06	1.32e-06	2.11e-06	1.58e-06	4.60e-07
Diethyl phthalate	-	3.46e-07	1.30e-06	< 8.21e-07	ND
Fluoranthene	1.86e-06	1.47e-06	2.63e-06	1.99e-06	5.91e-07
Fluorene	1.47e-06	1.21e-06	2.50e-06	1.73e-06	6.83e-07
Naphthalene	7.29e-05	6.89e-05	1.10e-04	8.38e-05	2.24e-05
Phenanthrene	5.87e-06	5.71e-06	9.94e-06	7.17e-06	2.40e-06
Phenol	9.61e-06	1.14e-05	2.57e-05	1.56e-05	8.80e-06
Pyrene	1.29e-06	1.09e-06	1.92e-06	1.43e-06	4.29e-07

[a]Pesticide sampler.
[b]Below detection limit.
[c]Not determinable.
[d]Sample concentration became a negative value when corrected for background concentration.

Table 5.75. Emission Factors for Metals from the Burning of Diesel Fuel and Dunnage.

Analyte	Trial 1 (g/g)	Trial 2 (g/g)	Trial 3 (g/g)	Average (g/g)	Standard Deviation (g/g)	PM_{10}[a] Sampler Trial 1 (g/g)	PM_{10} Sampler Average[b] (g/g)
Aluminum	5.96e-07	1.25e-06	2.96e-07	7.13e-07	4.87e-07	1.97e-03	1.42e-03
Antimony	BDL[c]	BDL	BDL	ND[d]	ND	1.79e-03	BDL
Arsenic	BDL	BDL	BDL	ND	ND	BDL	BDL
Barium	-[e]	2.18e-08	1.61e-07	< 9.14e-08	ND	5.12e-04	4.70e-04
Cadmium	2.45e-07	2.82e-07	3.31e-07	2.86e-07	4.29e-08	7.17e-05	8.40e-05
Calcium	1.39e-05	5.55e-06	-	< 9.72e-06	ND	2.12e-02	1.85e-02
Chromium	1.52e-07	-	BDL	< 1.52e-07	ND	BDL	1.25e-04
Copper	-	-	-	-	ND	2.41e-03	1.57e-03
Lead	1.79e-06	1.62e-06	2.34e-06	1.92e-06	3.75e-07	7.68e-04	7.83e-04
Mercury	-	7.65e-10	-	< 7.65e-10	ND	3.07e-06	1.14e-06
Nickel	BDL	BDL	BDL	ND	ND	BDL	BDL
Potassium	2.65e-05	2.54e-05	3.47e-05	2.88e-05	5.08e-06	1.02e-02	1.07e-02
Sodium	4.64e-05	5.08e-05	1.08e-05	3.60e-05	2.19e-05	7.42e-02	5.13e-02
Titanium	-	7.25e-10	2.15e-08	< 1.11e-08	ND	3.33e-05	1.57e-05
Zinc	6.41e-05	6.48e-05	5.90e-05	6.26e-05	3.17e-06	2.20e-02	2.14e-02

[a]Particulate matter less than ten microns in diameter.
[b]Average of trials 2 and 3.
[c]Below detection limit.
[d]Not determinable.
[e]Sample concentration became a negative value when corrected for background concentration.

Table 5.76. Concentrations of Semivolatile Organic Compounds (SVOCs) in the Burn Pan Residue Following the Burning of Diesel Fuel and Dunnage.

Analyte	Composite of Trials 1, 2, and 3 (µg/kg)
Acetophenone	940
Naphthalene	490
Dibenzofuran	120
Biphenyl	190

Table 5.77. Concentrations of Metals in the Burn Pan Residue Following the Burning of Diesel Fuel and Dunnage.

Analyte	Composite of Trials 1, 2, and 3 (mg/kg)
Aluminum	14,000
Antimony	BDL[a]
Arsenic	BDL
Barium	210
Cadmium	0.6
Calcium	20,000
Chromium	48
Copper	52
Lead	63
Mercury	BDL
Nickel	26
Potassium	4900
Sodium	8700
Titanium	93
Zinc	5000

[a]Below detection limit.

SECTION 6. DISCUSSION

The detonations of amatol and tritonal surrogates in the presence of water were done to provide preliminary emission factor data on a blast and noise suppression technique developed in the U.S. and refined in Europe. This technique, which involves detonating the munition with plastic bags containing water touching it, reduces the blast noise by more than 90 percent when compared to an equivalent unrestricted detonation (Reference 6). However, the water also quenches the fireball which could reduce the overall destruction efficiency of the detonation process. Amatol and tritonal were selected for this experiment because they represent two extremes in the oxygen content of commonly used explosives. When detonated, amatol, an oxygen-balanced explosive, contains sufficient oxygen to convert its carbon to CO_2, whereas, tritonal contains only 20 percent of the oxygen required to convert all its carbon to CO_2.

The detonations of amatol and tritonal surrogates in the presence of water yielded emission products for CO, VOCs, and SVOCs which were markedly higher and CO_2 emission factors which were lower than those resulting from the corresponding unrestricted detonations. For example, the CO_2 emission factor for amatol decreased by 60 percent and the corresponding emission factor for tritonal decreased by 55 percent. At the same time, the CO emission factors for amatol and tritonal increased by three orders of magnitude. Dramatic increases in the total alkene and total aromatic emission factors also occurred and substantially more soot was also evident from the detonations in the presence of water compared with the corresponding unrestricted detonations. The percent change in the emission factors for oxygen-deficient tritonal was essentially the same as that for the oxygen-balanced amatol.

The results from these and the previous BangBox studies are now being compiled and the resulting database statistically examined to determine if PEP materials can be classified into "emission product families" based on the chemical composition of the PEP material. The statistical analysis will also determine: (1) if the number of background samples and/or field samples collected for each PEP material can be reduced or should be increased; (2) if the target analyte list, sampling methods, or the sample-collecting times should be changed; and (3) if there are artifact pollutants which should be removed from the test data. A database management system, which will provide access to the BangBox data via the DOD Munitions Items Disposition Action System (MIDAS), is also being developed.

SECTION 7. APPENDICES

APPENDIX A. REFERENCES

1. U.S. Army Armament, Munitions, and Chemical Command (AMCCOM), Rock Island, Illinois, Proceedings of the Technical Steering Committee, 1989.

2. 40 CFR 264.601.

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4. U.S. Army Armament, Munitions, and Chemical Command (AMCCOM), Rock Island, Illinois, Final Report, Development of Methodology and Technology for Identifying and Quantifying Emission Products from Open Burning and Open Detonation Thermal Treatment Methods, BangBox Test Series, Volumes 1, 2, and 3, January 1992.

5. U.S. Army Armament, Munitions, and Chemical Command (AMCCOM), Rock Island, Illinois, Final Report, Development of Methodology and Technology for Identifying and Quantifying Emission Products from Open Burning and Open Detonation Thermal Treatment Methods, Field Test Series, Volumes 1, 2A, and 2B, January 1992.

6. Salter S.H. and Parkes J.H., The Use of Water-filled Bags to Reduce the Effects of Explosives, Proceedings of the 25th U.S. Department of Defense Explosive Safety Seminar, Miami, Florida, August 1994.

APPENDIX B. ABBREVIATIONS

AMCCOM - U.S. Army Armament, Munitions, and Chemical Command

CF - correction factor

CFR - Code of Federal Regulations

CP - command post

CVAA - cold vapor atomic absorption

DAS - data acquisition system

DIFS - detonation/ignition firing system

DOD - U.S. Department of Defense

DOE - U.S. Department of Energy

DPG - U.S. Army Dugway Proving Ground

ECD - electron capture detection

EM - energetic material

EPA - U.S. Environmental Protection Agency

FID - flame ionization detection

GC - gas chromatography

HBX - aluminzed composition B

HpCDD - heptachlorinated dibenzo-*p*-dioxin

HpCDF - heptachlorinated dibenzofuran

HxCDD - hexachlorinated dibenzo-*p*-dioxin

HxCDF - hexachlorinated dibenzofuran

IAW - in accordance with

ICP - inductively coupled plasma

LAN - local area network

LOI - letter(s) of instruction

MDT - mountain daylight time

MEM - mass of energetic material

MIDAS - Munitions Items Disposition Action System

MS - mass spectrometry

MSAI - Mountain States Analytical, Incorporated

NMOCs - nonmethane organic compounds

OB - open burning

OCDD - octachlorinated dibenzo-*p*-dioxin

OCDF - octachlorinated dibenzofuran

OD - open detonation

OES - optical emission spectrometry

OGI - Oregon Graduate Institute of Science and Technology

PeCDD - pentachlorinated dibenzo-*p*-dioxin

PeCDF - pentachlorinated dibenzofuran

PEP - propellant, explosive, and pyrotechnic

PETN - pentaerythritol tetranitrate

PM_{10} - particulate matter less than ten microns in diameter

ppmv - parts per million volume

pptv - parts per trillion volume

PS - pesticide sampler

PVC - polyvinylchloride

RCRA - Resource Conservation and Recovery Act

RDX - hexamethylenetrinitroamine

SERDP - Strategic Environmental Research and Development Program

STP - standard temperature and pressure

SVOCs - semivolatile organic compounds

TCDD - tetrachlorinated dibenzo-*p*-dioxin

TCDF - tetrachlorinated dibenzofuran

TNMHCs - total nonmethane hydrocarbons

TNT - trinitrotoluene

TSP - total suspended particulate

TUHCs - total unidentified hydrocarbons

UK - United Kingdom

USC - United States Code

VOCs - volatile organic compounds

WDTC - West Desert Test Center